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THE ANALYSIS OF STRAIN AND ITS GRAPHICAL REPRESENTATION.

By A. H. WILLIS, B.Sc.(Eng.), Wh.Sc., A.M.I.Mech.E.

THE development of electrical-resistance and other types of strain gauges has opened up a new field of experimental stress analysis. Many engineers, however, are finding that their knowledge of the theory of strain is inadequate for making the best use of this technique. Generally speaking, strain analysis is not treated comprehensively in engineering colleges for the reason that the subject of strength of materials is too wide in scope to allow any but the bare fundamentals to be given to students. Furthermore, it is only in the past ten years or so that a convenient practical application of the theory has been available. For the latter reason, too, the information required is not readily obtained from standard text-books. It is hoped that what follows will serve as an introduction to the subject of strain analysis and that it will be of particular value to engineers intending to adopt strain-gauge equipment in their research and development work. Particular emphasis has been placed on the graphical representation of strain, since the mathematical formulæ, while fairly easily developed, are cumbersome in use, and graphical methods not only yield solutions quickly but assist in the understanding of the subject.

A two-dimensional system of strain may be resolved into two direct components of strain, ϵ_x and ϵ_y, along two rectangular axes O X and O Y, together with a shear strain ϵ_{xy} which tends to change the angle between the axes. Each of these components has an effect in a direction inclined to O X, and the total effect may be obtained by superposition.*

Referring to Fig. 1, herewith, let O A B C be a body subjected only to strain ϵ_x in the direction O X; then the deformed shape will be the dotted figure O A B′ C′, such that $\frac{C C'}{O C} = \epsilon_x$. If the diagonal O B is inclined at the angle θ to O X, the strain in O B is given by

$$\epsilon_\theta = \frac{B' D}{O D}.$$

Since $\delta\theta$ is a very small angle, the change in the angle θ may be neglected and the expression becomes

$$\epsilon_\theta = \frac{B B' \cos\theta}{O B} = \frac{C C' \cos\theta}{O C \sec\theta} = \epsilon_x \cos^2\theta. \quad (1a)$$

Similarly, strain ϵ_y, acting alone, will produce a strain

$$\epsilon_\theta = \epsilon_y \cos^2(90 - \theta) = \epsilon_y \sin^2\theta. \quad (1b)$$

The shear strain ϵ_{xy} will deform the body as shown in Fig. 2, such that the angle $B C B' = \epsilon_{xy}$, O C is fixed, and B C = B′ C. Since the angle O C B is a variable, the relationship between the three sides of the triangle O C B must be stated in the general form:

$$O B^2 = O C^2 + B C^2 - 2\,O C\,B C \cos \widehat{O C B}.$$

Hence,

$$2\,O B\,\delta O B = 2\,O C\,B C \sin \widehat{O C B}\,\delta \widehat{O C B}$$
$$= 2\,O C\,B C 1\,\epsilon_{xy}.$$

Dividing throughout by $O B^2$,

$$\frac{\delta O B}{O B} = \epsilon_\theta = \frac{O C}{O B}\frac{B C}{O B}\epsilon_{xy};$$

therefore

$$\epsilon_\theta = \epsilon_{xy} \cos\theta \sin\theta = \tfrac{1}{2}\epsilon_{xy} \sin 2\theta. \quad (1c)$$

Hence, summating the effects of ϵ_x, ϵ_y and ϵ_{xy}

$$\epsilon_\theta = \epsilon_x \cos^2\theta + \epsilon_y \sin^2\theta + \tfrac{1}{2}\epsilon_{xy} \sin 2\theta. \quad (2a)$$

Expanding $\cos^2\theta$ and $\sin^2\theta$ in terms of $\cos 2\theta$, we obtain

$$\epsilon_\theta = \tfrac{1}{2}\left\{(\epsilon_x + \epsilon_y) + (\epsilon_x - \epsilon_y)\cos 2\theta + \epsilon_{xy} \sin 2\theta\right\}. \quad (2b)$$

When ϵ_θ is a maximum or minimum, $\frac{d\epsilon_\theta}{d\theta} = 0$, and this condition is satisfied when

$$\tan 2\theta = \frac{\epsilon_{xy}}{\epsilon_x - \epsilon_y}. \quad (3)$$

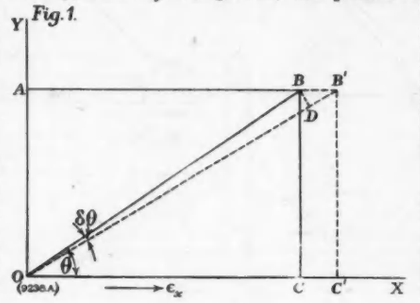
This equation gives two values θ and $(90 + \theta)$, and these angles will give the particular values $\epsilon_{max.}$ and $\epsilon_{min.}$ which are called the "principal strains." Equation (3) is represented graphically in Fig. 3, herewith; and when the values of $\sin 2\theta$ and $\cos 2\theta$ are substituted in equation (2*b*), we obtain

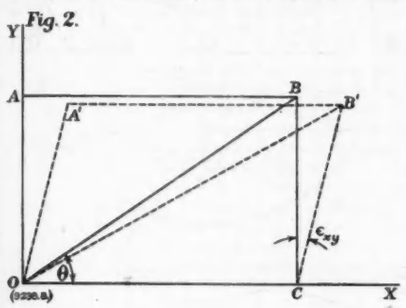
$$\frac{\epsilon_{max.}}{\epsilon_{min.}} = \frac{\epsilon_x + \epsilon_y}{2} \pm \tfrac{1}{2}\sqrt{(\epsilon_x - \epsilon_y)^2 + \epsilon_{xy}^2}. \quad (4)$$

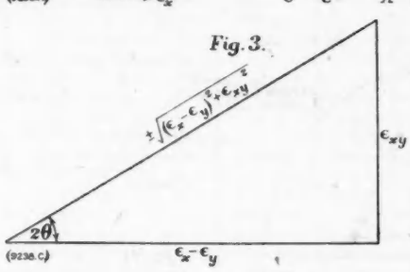
It will be noted that there is a similarity between the equations developed above and those obtained from considering the principal stresses in a simple system comprising two direct components of stress on planes at right angles and complementary shear stresses; and it may be concluded that a two-dimensional system of strain, as well as of stress, may be graphically represented by a simple Mohr circle.

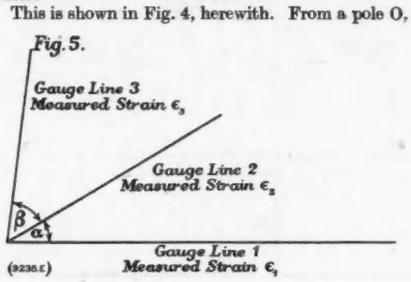
This is shown in Fig. 4, herewith. From a pole O, O A and O B are set off, equal to ϵ_x and ϵ_y, respectively, and A B is bisected at C. The perpendicular A N is of length $\frac{\epsilon_{xy}}{2}$; that is, half the shear strain. The circle of radius C N cuts the axis at P and Q, and it can be proved by reference to equation (4) that O P and O Q represent the principal strains, $\epsilon_{max.}$ and $\epsilon_{min.}$. Furthermore, the angle N C A satisfies equation (3) and thus equals 2θ; and, by geometry, the angles N Q A and N P M equal θ, the angle between the plane in which strain ϵ_x exists and the greater principal strain. It is evident that the planes of principal strain (by virtue of having zero shear strain) coincide with the planes of principal stress. It will be observed also that, since the double ordinate N A N′ represents the shear strain in a direction θ to the major principal strain, N A N′ will have maximum magnitude when $\theta = 45$ deg., that is, when N N′ becomes R R′. Thus the maximum shear strain is equal to the difference of the principal strains and occurs in a direction at 45 deg. to them.

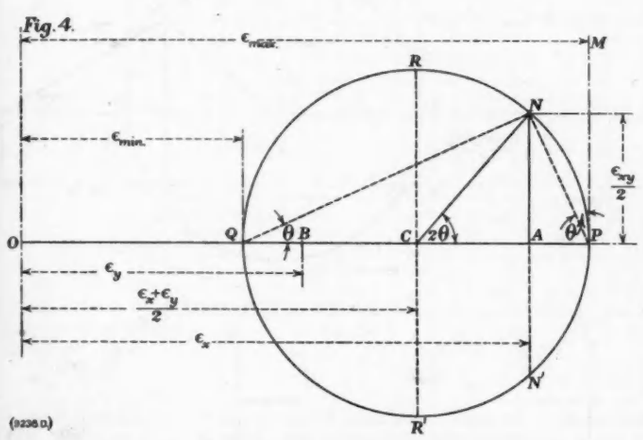
It is now necessary to establish the relationship between the principal strains and the principal stresses, $p_{max.}$ and $p_{min.}$, using the well-known

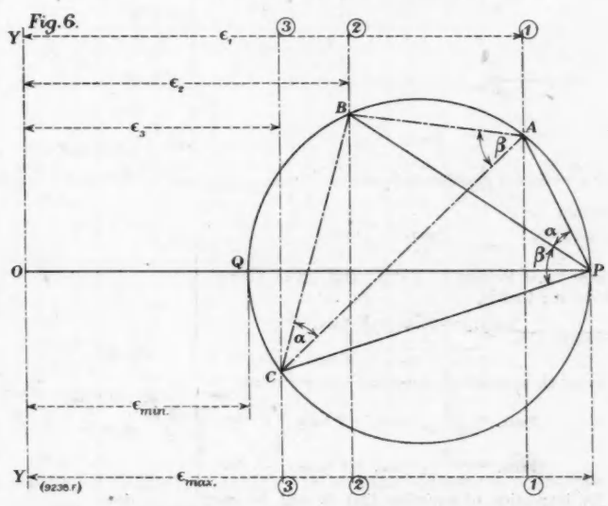












* *Strength of Materials*, by John Case. Third edition. Edward Arnold and Company, London (1938).

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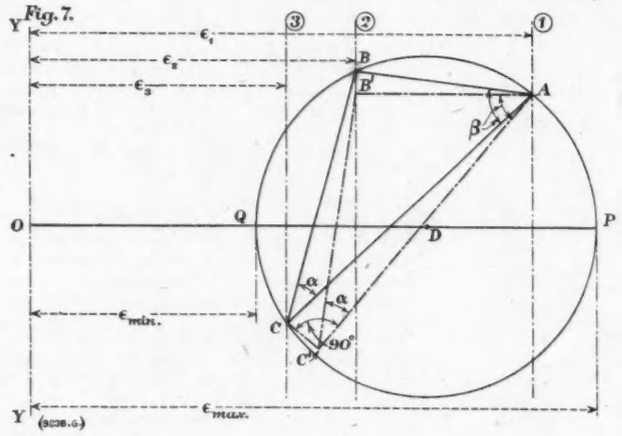
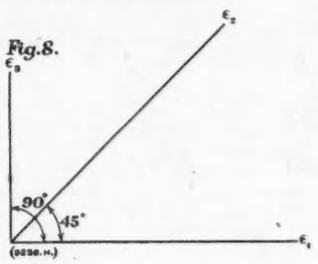
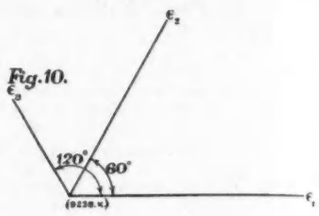
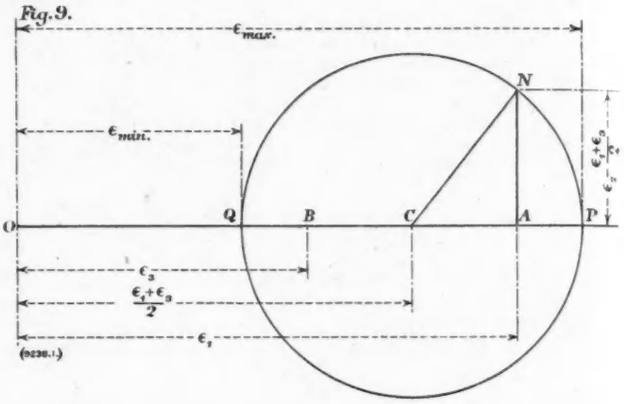
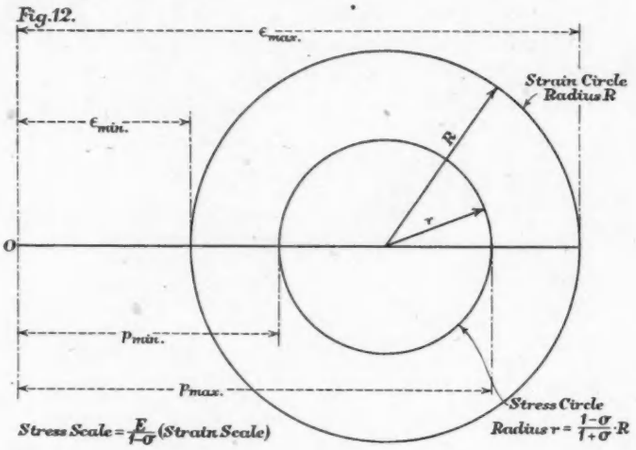
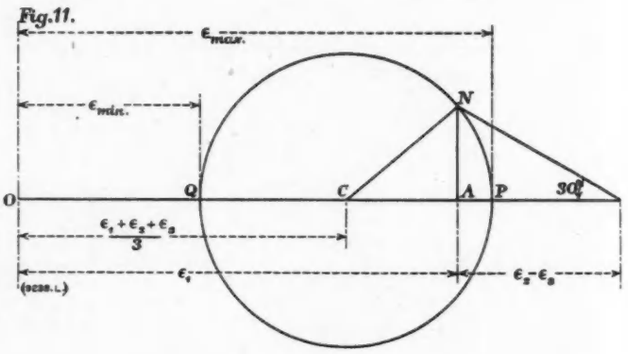












formula

$$\epsilon_{max.} = \frac{p_{max.}}{E} - \sigma\frac{p_{min.}}{E},$$

where σ = Poisson's Ratio and E = Young's Modulus; that is,

$$p_{max.} - \sigma p_{min.} = E\,\epsilon_{max.}.$$

Similarly,

$$-\sigma p_{max.} + p_{min.} = E\,\epsilon_{min.}.$$

Solving these simultaneous equations, we obtain

$$p_{max.} = \frac{E}{1-\sigma^2}(\epsilon_{max.} + \sigma\,\epsilon_{min.}) \quad . \quad (5a)$$

$$p_{min.} = \frac{E}{1-\sigma^2}(\epsilon_{min.} + \sigma\,\epsilon_{max.}) \quad . \quad (5b)$$

By inspection of equation (2a), it will be seen that it is necessary, in investigating a system of compound stress, to make measurements of strain in three known directions, as shown in Fig. 5, page 457. Such an arrangement is termed a "strain rosette." Mathematically, the problem is then to solve the three simultaneous equations which are obtained by considering the gauge line 1 as the plane of reference and substituting the measured quantities ϵ_1, ϵ_2, ϵ_3, α and β in equation (2a), namely,

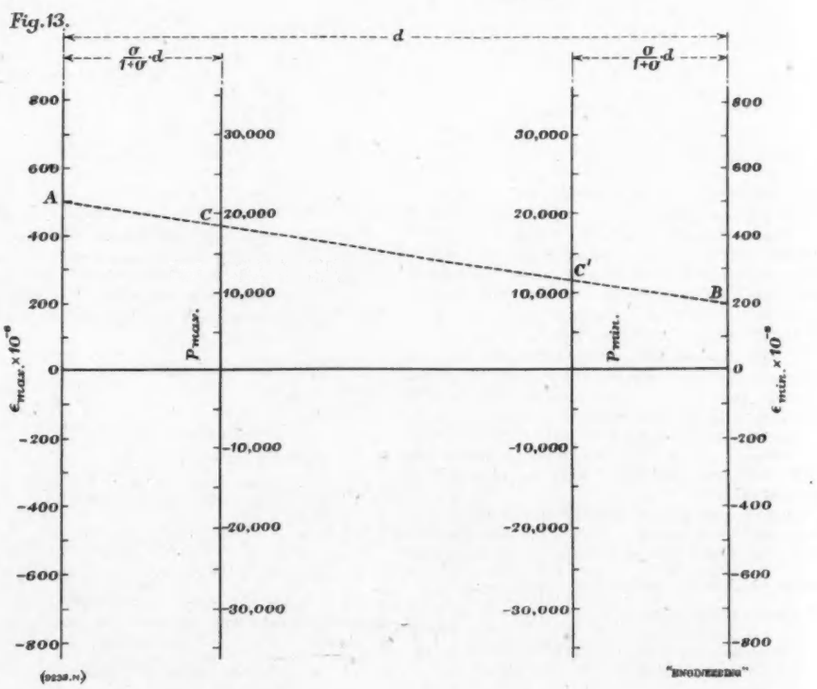
$\epsilon_1 = \epsilon_x$;

$\epsilon_2 = \epsilon_x \cos^2\alpha + \epsilon_y \sin^2\alpha + \frac{1}{2}\epsilon_{xy} \sin 2\alpha$; and

$\epsilon_3 = \epsilon_x \cos^2(\alpha+\beta) + \epsilon_y \sin^2(\alpha+\beta) + \frac{1}{2}\epsilon_{xy} \sin 2(\alpha+\beta)$.

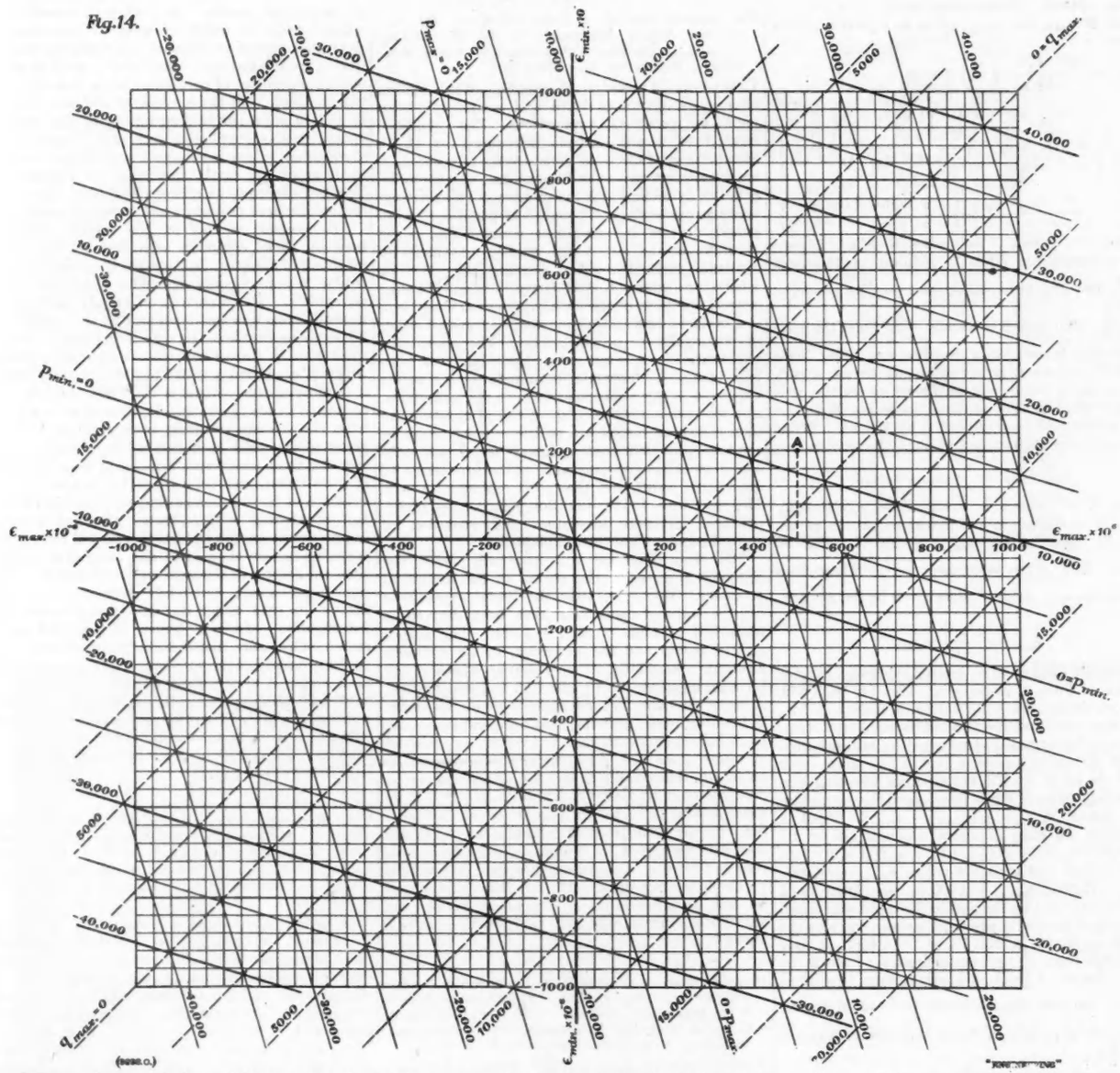
The values thus obtained for ϵ_x, ϵ_y and ϵ_{xy} are then substituted in equations (4) to find the principal strains, and the latter, in turn, are substituted in equations (5) to find the principal stresses.

The problem may also be treated graphically by means of the Mohr circle of strain. To a chosen scale, the strain measurements ϵ_1, ϵ_2, ϵ_3 are set off from the reference line Y O Y (Fig. 6, page 457); then the point A will lie somewhere in the line (1)(1), point B in the line (2)(2), and point C in the line (3)(3). It is also known that points A,



THE ANALYSIS OF STRAIN.

Fig. 14.



B and C must lie on a circle, and further, that the angle A P B ($= \angle$ A C B) must equal α, and the angle B P C ($= \angle$ B A C) must equal β. Graphically, therefore, the problem is to locate points A, B and C in their respective lines so that these conditions are satisfied. The circumscribed circle will then be the circle of strain.

Hansen* has given a simple geometrical construction which solves the problem, and this is shown in Fig. 7, opposite. The location of A in the line (1) is arbitrarily chosen, and A B′ is drawn at right angles to Y Y. The triangle A B′C′ is then constructed so that the angle B′C′A $= \alpha$ and C′A B′ $= \beta$. A perpendicular to A C′ is drawn from C′, cutting line (3) at C. The angle C A B, of magnitude β, is then constructed, thus giving the triangle A B C. It is easily proved that A C B and A C′B′ are similar triangles, and thus A B C is the required triangle. The centre D of its circumscribed circle is found by the usual method. The axis of the strain circle is, of course, the perpendicular from D to Y Y, and O P and O Q are the principal strains.

* H. M. Hansen. *Experimental Stress Analysis.* Vol. 1, No 1, page 138. Addison Wesley Press, Incorporated, Cambridge, Mass., U.S.A. (1943).

There are graphical methods also for finding the principal stresses, as will be shown later. When the angles between the gauge lines are 45 deg. or 60 deg., as is usual in practice, the arrangement of the strain rosette is regular, and simplified methods of treatment can be developed.

The 45 deg. or rectangular rosette is shown diagrammatically in Fig. 8, opposite. For the values 0, 45 and 90 deg. equation (2*a*) gives

$$\epsilon_1 = \epsilon_x;$$

$$\epsilon_3 = \epsilon_y;$$

$$\epsilon_2 = \epsilon_x \cos^2 45 + \epsilon_y \sin^2 45 + \tfrac{1}{2}\epsilon_{xy} \sin 90; \text{ or}$$

$$\epsilon_{xy} = 2\epsilon_2 - (\epsilon_1 + \epsilon_3).$$

Hence, substituting in equation (4),

$$\frac{\epsilon_{max.}}{\epsilon_{min.}} = \frac{\epsilon_1 + \epsilon_3}{2} \pm \tfrac{1}{2}\sqrt{(\epsilon_1 - \epsilon_3)^2 + (2\epsilon_2 - \epsilon_1 - \epsilon_3)^2},$$

which reduces to

$$\frac{\epsilon_{max.}}{\epsilon_{min.}} = \frac{\epsilon_1 + \epsilon_3}{3} \pm \frac{1}{\sqrt{2}}\sqrt{(\epsilon_1 - \epsilon_2)^2 + (\epsilon_2 - \epsilon_3)^2}. \quad (6)$$

The values of ϵ_x, ϵ_y and ϵ_{xy} given above may be applied to Fig. 4, and so give the construction shown in Fig. 9, on the opposite page.

The arrangement of the 60 deg. or equiangular rosette is shown diagrammatically in Fig. 10, opposite. In this case, equation (2*a*) gives

$$\epsilon_1 = \epsilon_x, \qquad \text{for } \theta = 0;$$

$$\epsilon_2 = \epsilon_x (\tfrac{1}{2})^2 + \epsilon_y \left(\frac{\sqrt{3}}{2}\right)^2 + \tfrac{1}{2}\epsilon_{xy}\frac{\sqrt{3}}{2} \quad \text{for } \theta = 60 \text{ deg.};$$

$$\epsilon_3 = \epsilon_x (\tfrac{1}{2})^2 + \epsilon_y \left(\frac{\sqrt{3}}{2}\right)^2 - \tfrac{1}{2}\epsilon_{xy}\frac{\sqrt{3}}{2} \quad \text{for } \theta = 120 \text{ deg.}$$

and, solving simultaneously,

$$\epsilon_y = \tfrac{2}{3}(\epsilon_2 + \epsilon_3 - \tfrac{1}{2}\epsilon_1), \quad \text{and}$$

$$\epsilon_{xy} = \frac{2}{\sqrt{3}}(\epsilon_2 - \epsilon_3).$$

Deducing the principal strains as before,

$$\frac{\epsilon_{max.}}{\epsilon_{min.}} = \frac{\epsilon_1 + \epsilon_2 + \epsilon_3}{3} \pm \tfrac{2}{3}\sqrt{(\epsilon_1^2 + \epsilon_2^2 + \epsilon_3^2) - (\epsilon_1\epsilon_2 + \epsilon_1\epsilon_3 + \epsilon_2\epsilon_3)}. \quad (7)$$

Fig. 11 *, opposite, shows the special graphical solution, the ordinate A N being equal to

$$\frac{1}{\sqrt{3}}(\epsilon_2 - \epsilon_3) \quad \text{or} \quad (\epsilon_2 - \epsilon_3) \tan 30 \text{ deg.}$$

There are several methods of finding principal

* *Photo-Elasticity*, by M. M. Frocht. Vol. I. John Wiley and Sons, Incorporated, New York (1941).

stresses, having ascertained the principal strains, and one of the most convenient is that given by Hansen,* who shows that the strain and stress-circle radii are simply related. Substituting in equation (5*a*) the values of $\epsilon_{max.}$ and $\epsilon_{min.}$ given in equation (4), we obtain

$$p_{max.} = \frac{E}{1-\sigma^2}\left\{\left(\frac{\epsilon_x+\epsilon_y}{2}\right)(1+\sigma) + \tfrac{1}{2}(1-\sigma)\sqrt{(\epsilon_x-\epsilon_y)^2+\epsilon_{xy}^2}\right\}$$

$$= \frac{E}{1-\sigma}\left\{\frac{\epsilon_x+\epsilon_y}{2} + \frac{1-\sigma}{1+\sigma}\cdot\tfrac{1}{2}\sqrt{(\epsilon_x-\epsilon_y)^2+\epsilon_{xy}^2}\right\}.$$

Hence,

$$\frac{p_{max.}}{p_{min.}} = \frac{E}{1-\sigma}\left\{\frac{\epsilon_x+\epsilon_y}{2} \pm \frac{1-\sigma}{1+\sigma}\,(\text{radius of strain circle})\right\}.$$

This means that, if the radius R (Fig. 12, page 458) of the strain circle is reduced in the ratio $\frac{1-\sigma}{1+\sigma}$, then the principal stresses may be measured from the same pole 0 to a scale $\frac{E}{1-\sigma}$ times the scale of strain. When strain rosettes are being used regularly, however, it is convenient to use a conversion chart which may be drawn up for the particular values of the physical constants E and σ. Such a chart has been published by Meier.† Referring again to equation (5*a*), this may be written

$$\frac{1-\sigma^2}{\sigma E}\,p_{max.} = \frac{1}{\sigma}\epsilon_{max.} + \epsilon_{min.};$$

which is, of course, a straight-line relationship. Thus, in Cartesian co-ordinates, particular values may be assigned to $p_{max.}$, giving a series of straight lines of the same slope $-\frac{1}{\sigma}$. These lines will cut the $\epsilon_{min.}$ axis at values given by the relationship

$$\epsilon_{min.} = \frac{1-\sigma^2}{\sigma E}\,p_{max.}$$

Equation (5*b*) may be treated similarly to give a series of lines of slope $-\sigma$. Fig. 14, page 459, has been drawn, using the values, $E = 30 \times 10^6$ lb. per square inch and $\sigma = 0{\cdot}3$. The number of stress lines may be increased as required by interpolation. It is of interest to note that lines of maximum shear stress are given by the dotted lines bisecting corresponding pairs of stress lines, since the maximum shear stress, $q_{max.} = \frac{1}{2}(p_{max.} - p_{min.})$. Point A represents the state of stress which is set up by principal strains of 500×10^{-6} and 200×10^{-6} in. per inch, and thus gives the values $p_{max.} = 18{,}000$; $p_{min.} = 12{,}000$; $q_{max.} = 3{,}000$ lb. per square inch.

A method used by the author for rapid conversion of principal strains to principal stresses employs the nomogram shown in Fig. 13, on page 458. It may be shown that, if two parallel axes of strain be drawn distant *d* from each other, then two intermediate parallel lines distant $\frac{\sigma}{1+\sigma}d$ from the strain axes give axes of stress, the scale of which is given by

$$\text{stress scale} = \frac{E}{1-\sigma}\,(\text{strain scale}).$$

Fig. 13 has been constructed for the same values of E and σ, as above. The same example is solved by marking off A = 500 on the left-hand axis and B = 200 on the right-hand axis; then A B cuts the stress lines at C and C′, giving $p_{max.} = 18{,}000$ and $p_{min.} = 12{,}000$ lb. per square inch, as before.

UNITED STATES CONFERENCE ON WEAR.—A summer conference on mechanical wear is to be held in Cambridge, Massachusetts, U.S.A., on June 14, 15 and 16, under the auspices of the Massachusetts Institute of Technology, the American Society of Mechanical Engineers, the General Motors Corporation, and the Chrysler Corporation. The conference will be devoted to a consideration of all aspects of wear between solid surfaces: its causes, symptoms and cures. The speakers will include Messrs. F. P. Bowden, H. Blok, J. O. Almen, E. Buckingham, P. S. Lane, and R. W. Dayton. Further particulars may be obtained on application to Professor J. T. Burwell, Junr., Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, 39, Massachusetts, U.S.A.

* *Loc. cit.*

† J. H. Meier. *Experimental Stress Analysis.* Vol. 1, No. 1, page 134. Addison Wesley Press, Incorporated, Cambridge, Mass., U.S.A. (1943).

LITERATURE.

The Symbolic Method of Vector Analysis: the "j" Operator Simply Explained. By W. H. MILLER, A.M.I.E.E. Classifax Publications, 9, White Moss-avenue, Manchester, 21. [Price 3*s.*]

THIS pamphlet presents the essentials of the algebra of complex quantities clearly and compactly with a view to practical applications. The symbolic method of vector analysis introduced by C. P. Steinmetz in 1893, and consistently advocated in his subsequent papers and books, has become indispensable in dealing with the problems of alternating-current engineering. Though it is possible to compound vectors by graphical construction, more accurate results are more readily obtained by symbolic methods. After defining the "*j*" or quadrature operator, and complex quantities—or general numbers, as the author prefers to term them—it is shown how the latter may be expressed either in rectangular or in polar form. The alternative exponential form is not given, but might well have been included. Formulæ for transforming a vector expressed in the rectangular form to the polar form, and vice versa, are deduced. General numbers are then shown to be subject to the ordinary rules of algebra, provided that ordinary terms are only added to ordinary terms and quadrature terms to quadrature terms, and that j^2 is replaced by -1. The procedures for the addition, subtraction, multiplication, division, involution and evolution of general numbers are then explained.

The clear diagrams will materially assist the beginner in grasping the nature of the analytical processes. Moreover, after the literal expressions for the various operations have been derived, a numerical example of each is given. The author rightly points out the necessity, in all symbolic algebraic operations, of considering whether any physical meaning can be attached to the operation. A list of the main formulæ appears in an appendix. It is unfortunate, perhaps, that temperature should be included along with mass and volume as examples of scalar quantities, since, though temperature, as ordinarily defined, obeys the law of equivalence, it does not obey the law of accumulation. It is more usual to write a vector with an arrow rather than a dot over the corresponding symbol; the dot is still currently employed to denote differentiation with respect to time. Although applications to practical problems are not dealt with, Mr. Miller states that he has in preparation a companion booklet on alternating-current vectorial analysis by symbolic algebra.

Progress Report on Triaxial Shear Research and Pressure Distribution Studies on Soils: United States Waterways Experiment Station. U.S. War Department, Corps of Engineers: Mississippi River Commission, Vicksburg, Mississippi. [Price 3·0 dols.]

THIS document is in two sections; firstly, a summary by P. C. Rutledge of the results of an extensive research project into the triaxial shear test carried out at Harvard University, the Massachusetts Institute of Technology and the Waterways Experiment Station between 1940 and 1944; and secondly, a review by D. W. Taylor of the uses of pressure cells in estimating the distribution of stresses in dams, behind retaining walls and under pavements. The research in both cases was carried out for the United States Army.

The report on triaxial shear is of importance to those who use this as a routine soil-mechanics test. It draws attention to the effects of membrane stiffness and piston friction when the axial load is measured outside the pressure chamber and shows how these are responsible for an apparent shear strength in a cohesionless soil at zero normal stress. Among the many results of interest to the research worker is that the ratio of height to diameter of specimen should be not less than 1·5 and not greater than 2·5: within these limits, the ratio appears to be immaterial. It is shown that considerable care is necessary in the preparation of specimens, and for cohesive soils it is recommended that cylindrical specimens be prepared by turning in a simple lathe instead of by the more general method of using a sampling tube. For cohesionless soils the speed of testing was found to have little effect. For cohesive soils, three types of test are examined: "quick" tests, in which no drainage of pore water is permitted during the test; "consolidated-quick" tests, in which drainage of pore water is permitted during preliminary consolidation but not during the triaxial test; and "slow" tests, in which complete drainage of pore water takes place throughout the test. All three types of test are required to obtain a proper understanding of the strength characteristics of cohesive soils and, in general, all three must be carried out for a complete stability analysis of an earth dam and its foundations. Detailed descriptions of apparatus and recommendations for test procedure are given in appendices.

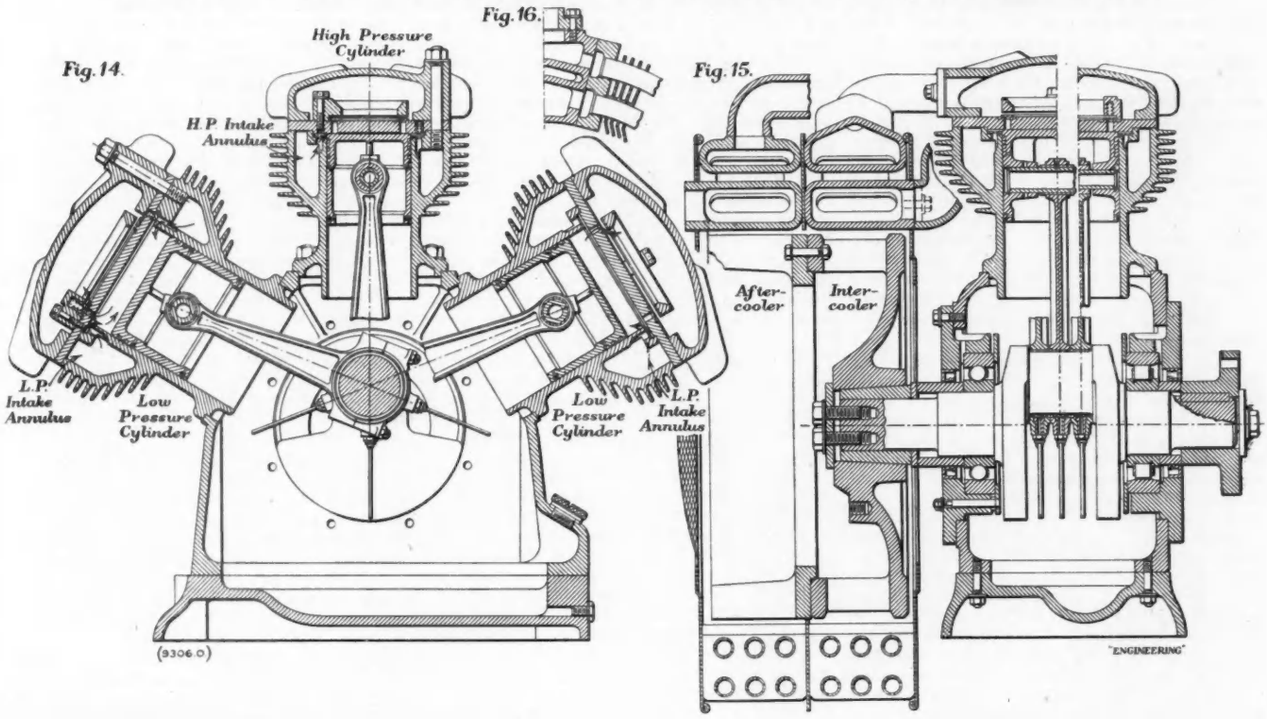
The second section of the report should be read by those engineers who wish to verify soil mechanics theories by installing pressure cells behind retaining walls or under earth dams and pavements. The pressure cell mainly used in the investigations was one developed by the Waterways Experiment Station. In this cell, pressure on the front face is transmitted to a diaphragm, behind which is cemented a resistance strain gauge, while a dummy gauge, which is an exact duplicate, is cemented inside the gauge chamber so as to be free from the stresses resulting from external loading. Many of the cells used had a life of only a few months, their sensitivity decreasing from the date of installation, and throughout the report there is evidence of the mechanical imperfections of the cell and connecting cable. These, although a great improvement on the Goldbeck cell, will have to be perfected before they yield any conclusive results, since the scatter in the tests was considerable. The report, previously published separately by the Station in 1944 under the title *Soil Pressure Cell Investigation: Interim Report*, is preceded by a review of pressure distribution theories which is a useful summary of the subject. The reports, having been prepared by a number of authors, do not read easily and there is a considerable amount of repetition; nevertheless, the information is quite the most valuable which has been published on the two subjects, and should be read by those engaged in either field of activity.

Fluid Mechanics of Turbomachinery. By G. F. WISLICENUS. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 7·50 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 45*s.*]

THE author of this book has succeeded in making a valuable contribution to knowledge of fluid machines by his thorough investigation of the wide range of problems involved in the dynamic design of water, steam and gas turbines, and of pumps and compressors. Although his approach is mainly theoretical, it is quite evident that, in every step, he is aware of physical reality. Sections are devoted to consideration of similarity relations, one of the more important aspects of design work since it is desirable to reproduce in larger or smaller machines the performance of any one satisfactory machine. The well-known Moody correction for efficiency is mentioned, but it is to be regretted that no definite index for the Moody formula is suggested in the general case of equal metal surfaces of model and prototype. This general case represents normal industrial production of a range of machines where the surface, generally cast iron or cast bronze, is finished to the same standards on the whole range. For comparison with British experience, some indication of the value of this index for the general case would have been appreciated.

The author gives a chart of single-stage centrifugal pump efficiencies, which appears to set a standard of what can reasonably be achieved. At the same time, however, this chart, which is based upon gallons per minute and specific speed, allows considerable latitude on the remaining variables of head and speed. A very thorough investigation of cavitation of water turbines and centrifugal pumps is given; starting from the Thoma parameter, the argument is developed, through the notion of suction specific speed, to examples of dimensionless charts based upon more recent American research. The author does not, however, indicate any variation

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.



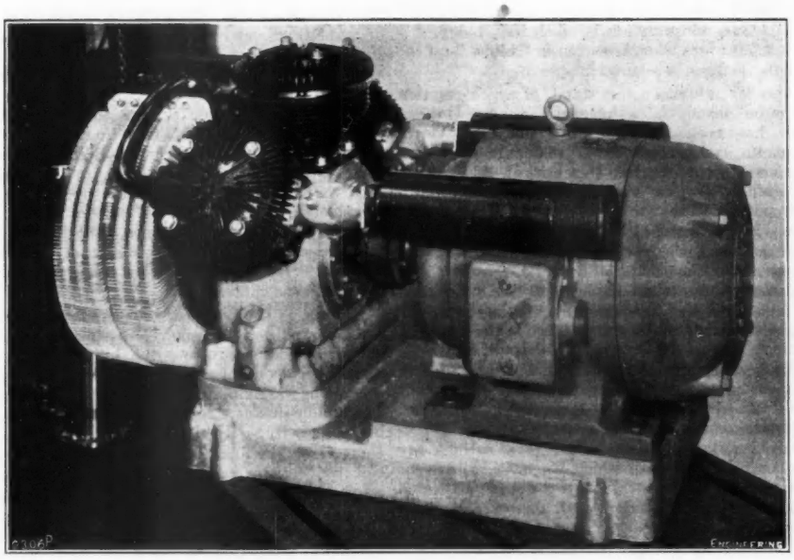


FIG. 17.

FIGS. 14 TO 17. THREE-CYLINDER AIR-COMPRESSOR; MESSRS. ALFRED BULLOWS AND SONS, LIMITED.

of cavitation behaviour between large and small machines. The section dealing with the theory of flow in hydrodynamic machines is logically presented in suitable steps, starting from the simple one-dimensional flow problems. The method of dealing with the geometry, although very detailed, should be of considerable value to designers. A method is developed of dealing with the important factor of over-lap of runner blades, a point which has been somewhat neglected in the past.

The sections on compressible fluids start from the basic principles of thermodynamics and cover the general cases of compressors and gas turbines, together with an investigation of similarity conditions. At the end of the book several valuable characteristic diagrams are provided, indicating flow coefficients on a dimensionless basis. Finally, there is an investigation of the geometry of fluid machines, which lays down several basic principles of design. Although it is apparent that the author's experience has been mainly concerned with pumps, his impartial approach ensures that the book does not suffer in any sense on this account. To designers of turbo machinery, this book will be of great value, largely because it is written by a designer who has the necessary theoretical knowledge and, at the same time, a practical experience wide enough to make him fully aware of the possibility of a difference between theoretical investigations and actual fact. This point is emphasised in his observation that "Very little is yet known about the real reason for such favourable results in some cases of pump and turbine design and for less favourable results in others."

THE BRITISH INDUSTRIES FAIR.

(*Continued from page* 439.)

THE Birmingham section of the British Industries Fair, which closes to-day, has attracted a large number of visitors of all classes. Of these, the most important, from the point of view of the exhibitors, are the buyers, for whom, it may be stressed, the various well arranged and informative displays are primarily intended. Without labouring the point, it may be added that the Fair is not, or should not be, an exhibition of inventions or of ideas embodied in apparatus which has not yet reached the commercial stage. It is therefore rather surprising that a "road transport gas turbine" should have been shown, and has been given excessive comment in the daily Press, since the unit is incomplete and has not yet been tested. Its designers are Messrs. Centrax Power Units, Limited, Half Acre, Brentford, Middlesex, and it is estimated that it will develop 160 brake horsepower. Its principal components are, or will be, a compressor running at 40,000 r.p.m. with eight axial stages and one centrifugal stage; a two-stage turbine driving the compressor; a single-stage power turbine with a speed of 35,000 r.p.m.; seven flame tubes; and worm reduction gearing for transmitting the drive to the vehicle. It weighs about 250 lb., and has been designed to burn kerosene or light Diesel oil. The main part of the unit was exhibited on the stand of the Ministry of Supply, in the section of Messrs. Power Jets (Research and Development), Limited. The Ministry state that it "can be used as a portable high-speed generator, a marine engine, or a light aircraft engine."

Turning to other exhibits, a range of air compressors of unusual and interesting design is displayed on the stand of Messrs. Alfred Bullows and Sons, Limited, Long-street, Walsall, Staffordshire. The two-stage machines work at a pressure of 100 lb. per square inch at the normal speed of 960 r.p.m., but the single-stage machines are limited to 55 lb. per square inch. The maximum working pressure at continuous rating of the two-stage machine is 200 to 250 lb. per square inch. The range of sizes is from 27 to 216 cub. ft., per minute. All these models have either two or three cylinders; in the latter case, there are two

low-pressure cylinders and one high-pressure cylinder. A photograph of a three-cylinder compressor is reproduced in Fig. 17, on page 461, and sectional drawings are shown in Figs. 14, 15 and 16; on the same page. The feature of greatest interest is the arrangement of coolers. These consist of an intercooler and an after-cooler, the latter ensuring that the compressed air is at not more than 20 deg. F. above the ambient temperature. The flow of air over the coolers is effected by the action of a double-entry centrifugal fan, which is integral with the flywheel. This fan draws air from the atmosphere through a protective grill, and blows it between steel-sheet fins surrounding double banks of ¾-in. copper tubes. After assembly, the coolers are dip-tinned to ensure the maximum rate of heat transfer. Cowlings, which are not shown in Fig. 17, are fitted to concentrate the flow of air. Fig. 16 shows a section through the cooling tubes and the after-cooler header.

In the three-cylinder compressors, the high-pressure cylinder is placed vertically between the two low-pressure cylinders, which are set at an angle. The crankcase is an aluminium-alloy casting. It is fitted with an exhalation valve for breathing and preventing the ingress of foreign matter, and allowing the compressor to work with a slight vacuum in the crankcase. The single-throw crankshaft is a Meehanite casting, and runs in ball and roller bearings. The connecting rods are Duralumin stampings, and the pistons are of cast iron in the smaller sizes and aluminium in the larger sizes. In all cases, the piston stroke is 3 in. The cylinders are of alloy cast-iron with ribs for air cooling, and the bores are honed to a mirror finish. The valve gear is of the Bullows's patented design. The inlet valve consists of a thin ring of chrome-vanadium steel, of greater diameter than the cylinder. It is seated on the top of the cylinder block and admits air through ports from an annulus surrounding the bore. An intermediate plate, between the cylinder block and the cylinder head, provides a seating for the delivery valve. This is generally similar to the inlet valve, although it is of smaller diameter. Both valves are held by several helical springs. The makers claim that this valve gear provides large passage areas and low gas velocities, with the result that high overall and volumetric efficiencies are obtained. The volumetric efficiency at the designed speed of 960 r.p.m., and at 100 lb. per square inch discharge pressure, is stated to be between 83 per cent. and 85 per cent. Furthermore, the inlet and delivery ports are separated, and the whole of the finned cylinder head is thus available for cooling the delivery valve and air. The large port areas permit low valve lift, and the machines are therefore quiet in operation, and wear is slight.

Air is admitted to the low-pressure cylinders through Burgess combined intake filters and silencers, and from the low-pressure cylinder heads it passes through the intercooler to the inlet annulus of the high-pressure cylinder. After final compression, it flows through the after-cooler. The compressor is mounted on a bedplate with a suitable electric motor and flexible drive, but the machines can also be supplied with a directly-mounted motor, which renders the bedplate and the flexible coupling unnecessary. For this purpose, the crankshaft is integral with the motor rotor. These compressors are also very light. Automatic unloading gear can also be provided if required.

The exhibits on the stand of the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, are arranged to illustrate the company's contribution to the country's export trade. The centre of the stand is devoted to an illuminated display of the world markets supplied, while round it are a number of examples of aeronautical accessories, process-heating equipment, street-lighting fittings, radio apparatus, and household appliances. A selection of electronic testing instruments and some models of the larger engineering products of the company are also on view.

Among the apparatus exhibited is an infra-red oven for pre-casting plastic materials prior to moulding. This has been designed to replace the usual patterns of convection oven for moulding work where rapid heating rates and a high degree of uniformity are not required, the material being heated by radiation from thermostatically controlled panels at the top and bottom. Pallets, powder and flake can be heated at a much faster rate than in the old type of oven, and can therefore be taken to a higher temperature without risk of pre-curing. The result is that a much shorter press cycle can be adopted so that the output can be increased by some 30 per cent. The risks of inserted pins breaking or of porosity in the mouldings occurring are also said to be reduced. The external shell of the oven is of mild steel sheet with light-alloy castings at the front and rear. The front casting is easily removable, so that access to the interior for cleaning and maintenance is facilitated. The heating chamber proper is supported within the casing and is insulated from it by glass-silk lagging. The radiating panels are supported from the top and bottom of the heating chamber. The electrical control box is attached to the right-hand side of the main casing. The charge is carried on two trays, which are supported on angle runners, while a third tray is provided to collect spillage and prevent it from falling on to the lower heating panel. The heating panels themselves are made of 10-in. by 8-in. heavy-gauge sheet-steel plates, each of which carries four heating elements. They are mounted sufficiently far from the surface of the charge to prevent any risk of small changes in the thickness of the latter causing uneven heating. The temperature of the radiating panels is controlled within about ±5 deg. C. by a rod thermostat which operates on the upper panel. A control knob enables the temperature of the plates to be adjusted from 100 deg. to 280 deg. C. The oven is designed to run on a 200 to 250-volt 50-cycle single-phase circuit. At 240 volts the power consumption with all the elements in circuit is 1·1 kW. This, however, is only required during the heating-up period, which lasts about 15 minutes. Subsequently the consumption is much less, being only about 250 watts when the oven is "idling" on the middle thermostat setting.

Another exhibit on this stand, of which mention may be made, is a magnetic sorting bridge. This has been designed for comparing ferro-magnetic components made under mass-production conditions or for the critical analysis of individual samples by comparison with known test pieces. The test samples may vary from thin wires to material several inches in diameter, provided that the specimen under test and the standard for that material are of the same shape and size. The method employed in this instrument is based on the measurement of the hysteresis characteristic of the material, which is under examination; and on the fact that the shape of a hysteresis loop varies with the composition of the material. The instrument itself consists of a bridge circuit two arms of which contain test coils, in which the standards and specimens to be tested are respectively inserted. The indicator is a cathode-ray oscilloscope the trace of which, when the adjustment is correct, is a horizontal line if the specimen tested is identical with the sample. If there is any difference, the traces will vary in shape and this variation can be interpreted by a skilled observer. The apparatus is arranged for connection to a 220/230 single-phase supply, and its consumption is about 70 watts.

The British Thomson-Houston Company, Limited, Rugby, are exhibiting a wide variety of equipment. Among this, mention may be made of the air-insulated metal-enclosed vertical plugging switchgear, which is a post-war modification of a well-established class of equipment. This modification was made primarily to incorporate a new single-break arc-control circuit-breaker; opportunity, however, was also taken to improve the racking and interlocking mechanisms and to secure a more pleasing appearance by the employment of flush instruments and internally mounted relays and meters. The maximum rupturing capacity of this switchgear is now 150 MVA; and it is designed for voltages of 11, 6·6 and 3·3 kV, giving a maximum current up to 1,200 amperes. A view of a typical equipment, which shows the circuit-breaker withdrawn and raised from the tank, is given in Fig. 18, opposite.

The constructional features of this equipment to which attention may be called are that the circuit-breaker is of the single-break design with a self-compensated arc-control chamber. The plugging contacts are mounted in either porcelain or phenolic-bonded paper bushings and are heavily silver plated. On the 400-ampere and 600-ampere patterns, these contacts are of the multi-point type, while on the 800-ampere and 1,200-ampere equipment each contact is in three parts, comprising the breaker connector, a split-sleeve socket and a plug, which is fixed to the service connection. The halves of the socket are held together by a spring, which permits it to move to a limited extent on the circuit-breaker connector. When the circuit breaker is raised, the socket is forced over the plug, making a high-pressure line contact between the socket, connector and plug. The circuit breaker can be arranged for operation either by hand, by solenoid or spring. When a spring is used it is charged manually and can be released either by a lanyard or electrically from a remote point. In each case the usual combinations of over-current trip, shunt trip and under-voltage release can be fitted. The circuit breaker is raised and lowered by bevel gears and a jack screw.

Examples of the air-break contactors, which have been designed by the firm for use on high-voltage polyphase alternating-current circuits and for the control of the stator circuits of induction motors driving mine hoists, hydraulic pumps, boiler-house fans, pulverisers and conveyors, are also on view. As will be seen from Fig. 19, opposite, which shows a 6·6-kV, 60-ampere contactor with one arc chute removed, the contactors used are of the electro-magnetic type and are constructed so as to be suitable for frequent operation. To facilitate cleaning and to provide access to all the wearing parts, chutes of the lift-off type are employed. Porcelain insulation is used throughout, except on the operating rods. The latter, however, are also of insulating material and have ample creepage surface. Provision has been made for the magnetic and contact gaps on each pole to be adjusted separately to their proper value. The contacts are fitted with compression springs and close with a combined rolling and sliding motion, thus tending to maintain ample contact between clean surfaces. The arc chute is so constructed, in conjunction with the blow-out system, as to rupture the arc effectively. It is wide at the bottom so that the contacts have ample clearance, and tapers to a narrow slot at the top to ensure that the arc is cooled as it is forced by the blow-out system up the horns into the chute.

Each pole of the contactor is mounted on a metal base carrying three porcelain insulators. The bottom insulator supports the hinged or moving contacts and one of the arcing horns; and has a connecting rod running through it to form a terminal. The middle insulator supports the fixed contact, the blow-out coil, the other arcing horn and the arc chute, while the top insulator supports the blow-out coil connection and arc chute. It also has a connecting rod running through it to form the other terminal. The poles of the contactor, when assembled on their metal bases, are bolted to horizontal angle iron members which, in turn, are fixed to vertical channel iron supports. The operating magnet and shaft are arranged on a horizontal channel iron, which is also fixed to the vertical supports. The operating levers, which are connected to each pole of the contactor by insulated operating rods, are clamped to a square shaft. The contactor is provided with a solid-steel clapper-type magnet with two operating coils.

During recent months, the versatility of fork-lift industrial trucks has been considerably increased by the introduction of ancillary equipment. Interest therefore attaches to the exhibit of Messrs. I. T. D., Limited, 142, Sloane-street, London, S.W.1, who are showing several attachments for use with their "Stacatruc" fork-lift truck, a description of which was given on page 559 of our 162nd volume (1946). One of these attachments is illustrated in Fig. 20, on page 468, where it is shown fitted to a standard truck. This combination has been designated the "Stacascoop" and, as will be seen from the illustration, it comprises a metal scoop which is fitted in place of the lifting forks. The unit consists

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

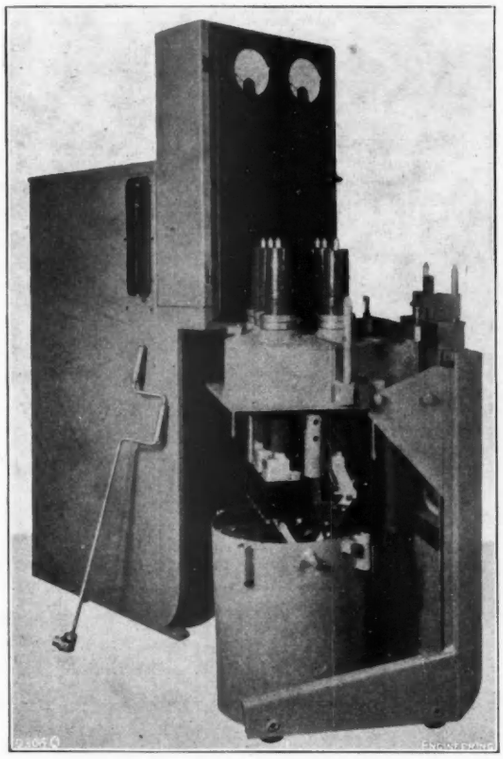


FIG. 18. AIR-INSULATED SWITCHGEAR; MESSRS. BRITISH THOMSON-HOUSTON COMPANY, LIMITED.

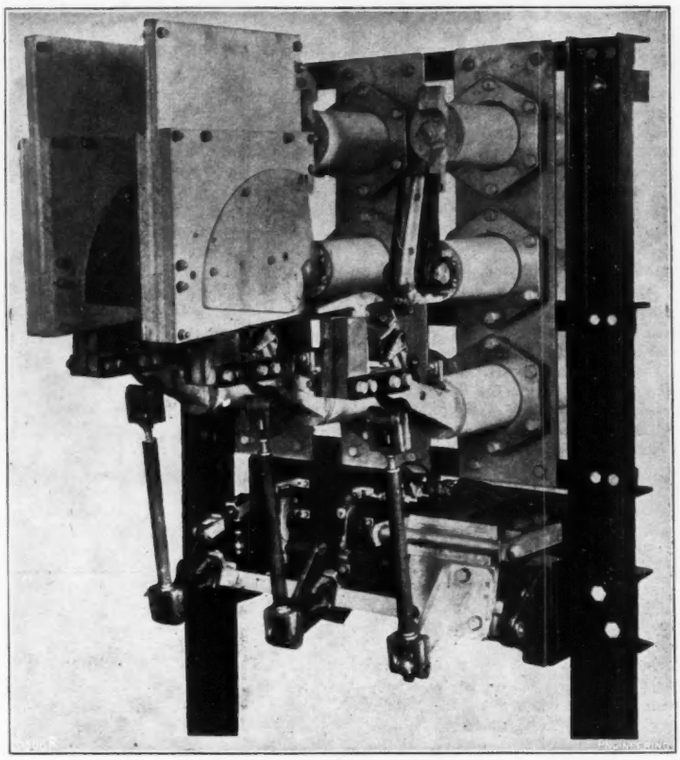


FIG. 19. HIGH-VOLTAGE CONTACTOR; MESSRS. BRITISH THOMSON-HOUSTON COMPANY, LIMITED.

virtually of two parts: the scoop itself and the supporting brackets. These brackets are fitted to the ends of a cast-iron weight which, in turn, is bolted to the lifting frame of the truck. The object of the weight is to ensure the positive descent of the unit when empty. The scoop, which is of fabricated construction, is fitted to the supporting brackets through two trunnions which run in sealed bearings in the brackets. These trunnions are located towards the rear of the scoop so that, unless restrained, the front of the latter will hang downwards. It is, however, maintained in the position shown in the illustration by an automatic locking mechanism, which is fitted to the nearside scoop-support bracket and is released by a hand control. This hand control can be seen in the illustration just above the steering wheel. To load the scoop, the locking gear is released, the height of the lifting frame is adjusted so that the leading edge of the scoop just clears the ground, and the truck is driven forward. As the scoop enters the material, the lifting frame is lowered, thus causing the scoop to return to the horizontal position. At the same time, the locking mechanism comes into operation and prevents the scoop from turning about its trunnions as it rises up the masts of the truck. The truck is then driven to the discharge point where the scoop may be raised to the full extent of the masts before the contents are discharged by releasing the locking gear. The scoop has a capacity of approximately $\frac{1}{3}$ cubic yard and the manufacturers state that it can be fitted in place of the lifting forks in a few minutes.

Messrs. H. E. C. Compressors and Engines, Limited, Levis Works, Stechford, Birmingham, 9, are among the many firms exhibiting small compressors. An example of these machines, which are suitable for builders, decorators and farmers, is illustrated in Fig. 21, on page 468. It is designed particularly for spray-painting and wash-spraying, and is fitted with a 2-h.p. J.A.P. engine, both compressor and engine being mounted on an electrically-welded receiver, 24 in. in length and 12 in. in diameter. The diameter of the compressor bore is $2\frac{5}{8}$ in., the piston stroke is $2\frac{3}{4}$ in. and the displacement is 6 cub. ft. per minute at 740 r.p.m. The delivery pressure may be adjusted to between 10 and 100 lb. per square inch by means of a reducing valve, and since a petrol engine cannot conveniently be stopped every time the pressure in the receiver has been built up, an unloader which bypasses the compressor delivery and allows the engine to idle is provided. Other fittings are: an oil and moisture trap for cleaning the delivery air, two pressure gauges, a safety valve and drain taps on the receiver, and an after-cooler. The compressor set is mounted on two pneumatic-tyred wheels and is fitted with a handle. The principal dimensions, excluding the handle are: length, 3 ft. 2 in.; width, 2 ft.; and height, 3 ft. 4 in.

Among the equipment exhibited by the transformer department of Messrs. Ferranti, Limited, Hollinwood, Lancashire, is a 1,000-kVA, 33/11-kV, 50-cycle outdoor transformer for three-phase circuits. This is fitted with fully-automatic on-load tap-changing gear of the camshaft contactor type, which is shown operating under the control of an astatic voltage relay. As will be seen from Fig. 22, on page 468, this gear is entirely self-contained and, it is claimed, requires no adjustment apart from periodical inspection of the contactors. The continuously rated reactor method of operation is employed, the contactor-type switch which interrupts the current being connected to tappings brought from the transformer windings, while the continuously rated bridging reactor is centre-tapped and connected so as to provide a maximum number of steps with a minimum number of contactors. In fact, eight tappings and contactors per phase can usually be arranged to give 15 voltage positions. The tap-changing switchgear is mounted in an oil-filled isolated compartment on the side of the main tank, which is separated from the transformer by an oil-tight insulating panel on which the contactors are mounted. Access to this compartment is facilitated by a hinged inspection door. All the moving parts operate under oil and no periodical oiling or greasing is required.

The tap-changing contactors are self-aligning with line contact throughout, so that the need for flexible braid has been eliminated. They are easily accessible and the moving finger can be removed and replaced without the use of spanners and, when replaced, is self-locating in its correct operating position. The cams, which operate the contactors, are mounted on synthetic-resin paper shafts. These are coupled together and to the driving mechanism through constant-mesh spur gears. The camshafts are driven through a Geneva wheel by a weight which is mounted in a vertical plane and is rotated by a simple induction-disc motor through spur gearing until it reaches the top dead centre. The weight then falls under the influence of gravity to complete one revolution and to make one tap change. The completion of a tap change, once it has been commenced, is thus assured. The time taken to raise the weight is about 50 seconds and the inherent time lag in the control circuit thus provided prevents tap-changing due to momentary fluctuations in voltage. The disc motor consists of two sets of iron-cored coils mounted on each side of a copper disc forming the rotor. Rotation is obtained by supplying one set of coils with a voltage which is in quadrature with that supplied to the other, this phase displacement being obtained by connecting a condenser in series with one set of the coils. The tap-changing gear can be remote controlled by a "raise-lower" switch or automatically, as in the unit shown at Castle Bromwich, by an astatic voltage relay. This relay is connected across the output terminals of the transformer.

Another interesting apparatus exhibited on this stand is the Ferranti-Jeans seed conditioner, which we illustrate in Fig. 23, on page 468. This has been designed to solve the problem of conditioning comparatively small quantities of seeds, especially of the more expensive varieties, when they have become damp due to storage or reaping conditions.

It consists essentially of a 0·4-h.p. single-phase motor which drives a blower with an output of 400 cub. ft. of air per minute. This air is heated by a 5-kV heater, which is controlled by a contactor, the latter being actuated by a bellows thermostat. The air temperature is thus accurately controlled and may be adjusted up to a maximum of 120 deg. F. by the dial on the front of the conditioner. In operation, a perforated spear is driven vertically into the centre of the sack of seed and placed under the machine. A sliding collar on the air outlet of the latter is next pressed firmly over the top of the sack spear and the motor started. Warm air is thus blown through the perforations in the spear into the seed, so that both internal and surface moisture are removed. When the moisture content of the seed has been reduced to the required value, cold air is blown through the seed until it reaches its normal temperature.

Among the instruments shown on the stand of Marconi Instruments, Limited, St. Albans, mention may be made of a direct-reading *p*H meter with a range from 1 *p*H to 11 *p*H. This instrument consists essentially of the electrode systems, an electrometer and the measuring circuit. The electrode system is of the standard laboratory type with a glass electrode and a calomel reference electrode, which are mounted in a two-piece moulded rubber assembly to form a single well-protected unit complete with non-reversible leads. The sensitive spherical membrane of the glass electrode is guarded by a surrounding glass sheath which projects beyond the rubber moulding. The filling tubulus of the potassium-chloride reservoir, which forms part of the reference electrode, also projects beyond the moulding. The electrode system has been designed to make electrode replacement easy without the use of tools. In the electrometer the potential from the glass electrode is applied to a four-element electrometer valve. This valve is mounted in a screened container which carries the "press-to-read" input switch and the highly insulated socket. The electrometer forms a complete individual unit in the assembly. A manual temperature comparator for use in the 10 deg. to 50 deg. C. range is incorporated in the measuring circuit to adjust the response so that the actual *p*H at working temperature is indicated. Basic overall standardisation, which includes the performance of the electrode cell chain, is carried out in the usual way by reference to a buffer solution of known *p*H value, the instrument itself being standardised by checking the low-tension voltage, adjusting the high-tension voltage and setting up the sensitivity against an internal reference voltage equivalent to an increment of 8 *p*H units at 20 deg. C. This simple procedure ensures that the performance of the instrument is independent of all possible variables, particularly changes in the high-tension voltage or in the valve parameters. The same firm is exhibiting a direct-reading electronic counter for counting up to 1,000,000 periodic or random impulses at rates up to 1,000,000 per second; or for the measurement of time intervals from 5 micro-seconds to one second in steps of one micro-second.

A number of panels on the stand of the Copper Development Association, Grand Buildings, Trafalgar-square, London, W.C.2, have been arranged to show the wide range and variety of applications for which copper and its alloys are used in many important branches of industry. Unusual specimens of copper in fabricated form include foil 0·0005 in. thick and 6 in. wide. This has been produced by cold rolling in commercial quantities and to exacting requirements. A deep spinning illustrates the high degree of manipulation to which copper can be subjected. This spinning was made from a flat copper disc, 22 in. in diameter by No. 19 S.W.G., and in its finished form comprises a vessel 18 in. deep with a diameter of 3 in. at one end and of 10 in. at the other. A piece of four-denier gauze, such as is used in the paper-making industry, is exhibited to show how brass, bronze and other copper alloys can be drawn into fine wire and woven. In the example on view, the warp is of bronze and the weft is of brass wire, the seams having been made by butt-welding each strand of the warp.

(To be continued.)

SPEED CONTROL OF DIRECT-CURRENT MOTORS.

MESSRS. METROPOLITAN-VICKERS ELECTRICAL COMPANY, LIMITED, MANCHESTER.

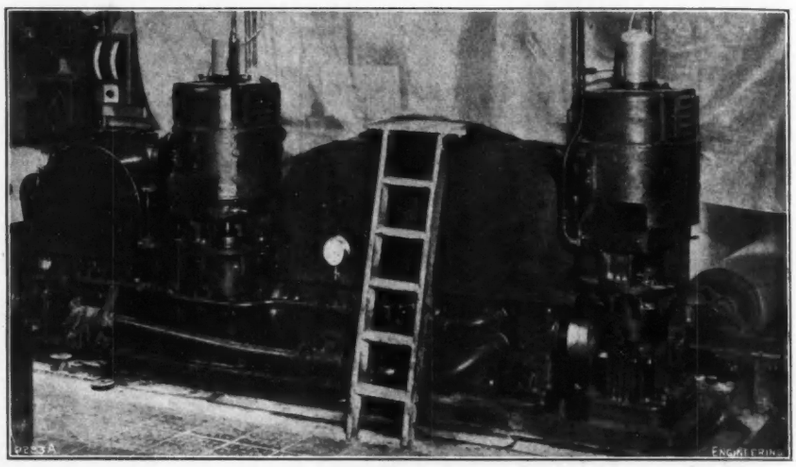
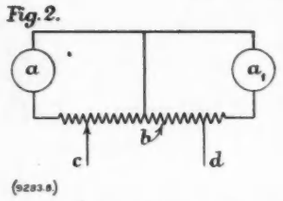


FIG. 1. SECTIONAL DRIVE OF CALENDER.

Fig. 2.



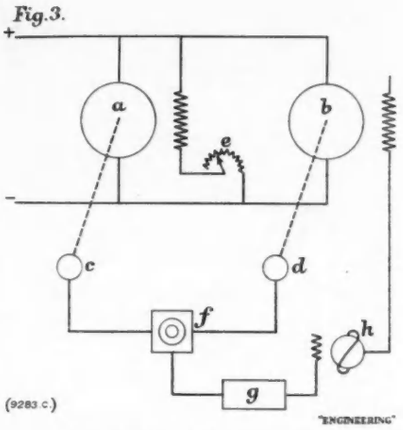
THE SPEED CONTROL OF DIRECT-CURRENT MOTORS.

PAPERMAKING machinery, printing presses, linoleum calenders and other similar plant are usually divided into two or more sections, each of which is driven by a direct-current electric motor. It is important that the relative speed of these motors should be accurately controlled and that any fluctuations which occur shall be corrected with the minimum disturbance. A system which, it is claimed, fulfils these conditions has been developed recently by the Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester, 17, and, we understand, has given good results in service. In this system a small tachometer generator, which produces a voltage proportional to its speed, is coupled directly to each motor and the outputs of two such generators, a and a_1, Fig. 2, are connected in opposition across a potentiometer b. If the two voltages developed are equal and the sliding contact c is adjusted so that it is symmetrical with the fixed contact d the voltage across $c\,d$ will be zero. Should the speed of either motor change, however, the resulting change in the tachometer voltage will appear across $c\,d$ and can be amplified and applied to the motor field, thus restoring synchronism as explained below. Similarly, if a permanent difference in speed between the two motors is required, the sliding contact c can be adjusted to give zero voltage across $c\,d$ when this difference exists. Any variation in the relative speeds of the two motors, however, will again produce a voltage across $c\,d$, so that the original speed relationship will be restored. The potentiometer, which may be calibrated in percentage speed difference, is mounted with the motor speed indicators to form a control station.

In order to maintain the relative speed of the two motors to within a fraction of 1 per cent. under all conditions, however, high amplification of the voltage across $c\,d$ is necessary. This is effected in two stages, the first of which consists of an electronic amplifier employing hard valves of the type used in ordinary radio receivers. The second stage consists of a Metadyne generator which, it may be recalled, requires only a minute exciting current and responds very rapidly to changes in the excitation. It therefore forms a suitable link between the output of the electronic amplifier and the field of the main motor.

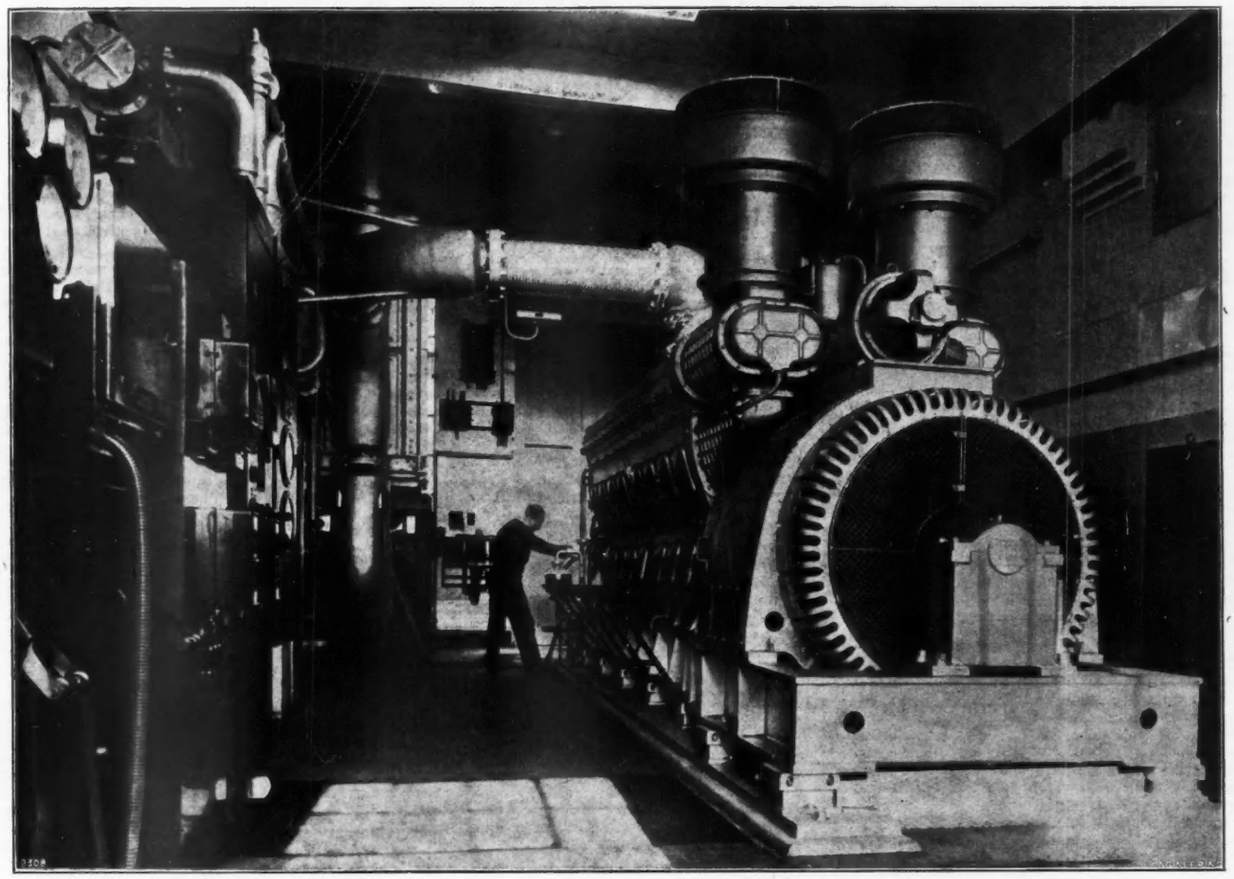
An example of this system of speed control is provided by a calender each section of which is driven by a 25-h.p. direct-current shunt-wound motor with a speed range of 3 to 1. When motors of standard design were employed, it was not easy to obtain the required sensitivity and stability over the full shunt range. Moreover, although it was not essential that the basic speed of the calender itself should remain constant within close limits, it was necessary that a relationship between the speeds of the motors should be accurately maintained. It was decided, therefore, to control one motor by hand and to design the control equipment so that the speed of the other should correspond with that of the first. This had the advantage that the cost and complication of the scheme were halved compared with what would have been necessary had each motor been controlled independently to a common reference. A diagram of the system adopted is given in Fig. 3, from which it will be seen that the leading and following motors, a and b, are provided with voltage generators c and d. The leading motor is controlled by the field rheostat e, while relative speed adjustment is effected by the potentiometer f. The control voltage is applied to the shunt field of the motor b through the electronic amplifier g and the Metadyne h. As shown in Fig. 1, the voltage generators are mounted on top of the vertical-spindle main motors, the control station and field regulators being visible on the extreme left of the illustration. The speed control and starting gear are housed in a totally-enclosed steel cubicle.

Fig. 3.



With this system it is possible also to stabilise the speed of a single motor fitted with either shunt-field or armature-voltage control by coupling a voltage generator to its shaft and backing its output against a voltage reference. Where several motors are used they can also be referred to a common standard or they can be "cascaded," as in the calender drive referred to above. When the speed range is wide, armature control would normally be used with a limited range of shunt-field control on the individual motors for trimming purposes. The advantages claimed for the system are high sensitivity combined with stability, simplification of equipment and the elimination of variable-speed gears or cone pulleys. In addition, any variation from the controlled speed is corrected with the minimum of transient disturbance.

DIESEL-ENGINED GENERATING PLANT.



DIESEL-ENGINED GENERATING PLANT.

SINCE the fuel crisis of early 1947 and the subsequent general shut-down of industry, many firms have installed Diesel-engine driven generating plant as an insurance against similar happenings. The installations, however, vary considerably, some of them being of a temporary nature and intended to act as a standby against failure of the mains supply, while others are of a more permanent character, being worked continuously and either supplementing the mains supply or taking the full load of the works. A good example of the latter type of installation is furnished by the Diesel-engined generating set illustrated above; this is installed in the works of Messrs. AC-Sphinx Sparking Plug Company, Limited, Dunstable, and is making a substantial contribution towards the easing of the load on the local power station.

The Diesel engine and alternator were supplied as a complete unit fitted to a common bedplate by the General Motors Corporation (Cleveland Diesel Engine Division), Cleveland, Ohio, U.S.A. The engine is a two-stroke, 16-cylinder V-type unit, the bore and stroke of the cylinders being 8½ in. and 10 in., respectively, and the maximum output being 1,440 brake horsepower. The combined crankcase and cylinder blocks are in the form of a fabricated steel structure, the main bearings being supported by inverted A frames welded to the top of the crankcase. The cooling-water and lubricating-oil manifolds are an integral part of this structure, the cooling water manifolds being formed by two parallel plates which extend along the base of each bank of cylinders, while the lubricating oil duct is formed where the two banks join at the top of the crankcase. Cast-iron cylinder liners are fitted, each liner having an integral water jacket formed by cored annular spaces between the inner and outer walls. Separate cylinder heads are used, and these take the form of circular iron castings the outside diameters of which are equal to the outside diameters of the liners. Each head is secured directly to its corresponding liner by eight studs and nuts, the studs being fitted into the top of the liner. The cylinder head and liner assemblies are located at their top ends by counterbored steel castings fitted into the top face of the cylinder block, into which the cylinder heads slide; and at their lower ends by holes bored in the two plates which form the cooling-water manifold. The annular cooling spaces for each liner are open at the bottom, and are sealed by rubber rings, one ring being trapped between a flange formed on the periphery of the outer wall of the liner and the upper plate, and the other between a flange formed on the periphery of the inner wall of the liner and the lower plate.

Each cylinder head is fitted with four exhaust valves operated through rockers from overhead camshafts. There is a separate camshaft for each bank of cylinders and one rocker arm operates two valves through a bridge piece. The camshafts are driven from the generator end of the crankshaft through a train of spur gears, the idling gears turning on stub shafts fitted to the end plate of the crankcase. The fuel injectors are fitted to the centres of the cylinder heads. They are of General Motors standard pattern and may be described as combined fuel-metering pumps and spray valves, the pumping elements being operated by the camshafts through rocker arms. The quantity of fuel injected is regulated by a Marquette governor which, within limits, can be adjusted to control the engine revolutions.

The crankshaft, which is manufactured in two sections, is carried in main bearings of the steel-backed white-metal lined type, the diameter of the journals being 7¼ in. The upper and lower bearing shells are held in position in the A frames by forged-steel bearing caps, the joints between the A frames and the bearing caps being serrated so as to ensure correct location of the caps. An accessory-driving gear is fitted to the forward end of the crankshaft and this drives the water-circulating pumps, the oil pumps and the governor. A harmonic balancer is fitted to the forward end of the crankshaft.

Cast-iron oil-cooled pistons are fitted; these are of the two-piece or floating type in which the body of the piston is supported by a separate gudgeon-pin casting, the two parts being held together by a snap ring. Each piston is provided with three compression and two oil-control rings, and is fitted with a hardened alloy-steel gudgeon pin, which works in bronze bushes. The connecting rods are of the interlocking blade-and-fork type, the blade rod, which works on the back of the upper bearing shell, being located by counterbores formed in the fork rod.

Scavenging air is provided by two helical three-lobed Root's blowers, one for each bank of cylinders. They are driven from the camshaft gears and deliver to trunks formed in the engine structure, the air entering the cylinders through ports formed in the liners in the usual manner. The air is drawn into the blowers through two combined silencers and oil-bath air cleaners, clearly visible in the illustration.

All bearings within the engine are supplied with oil under pressure, the crankshaft being drilled for big-end lubrication. An oil cooler is fitted in the lubricating system, the temperature of the oil being regulated by a thermostatically-controlled valve. The engine is water-cooled, the water being circulated by two centrifugal pumps situated at the forward end of the engine and driven, through gearing, from the crankshaft. A tubular-type heat exchanger is employed, the temperature of the engine being thermostatically controlled. The raw water for engine cooling is taken from a large reservoir situated in the grounds of the factory, the reservoir, in turn, being supplied from a deep well. This water system, which includes a purifying plant, was installed during the recent war as an alternative means of supply in emergencies.

As previously mentioned, the engine and alternator are fitted to a common bedplate; this is of fabricated construction and is isolated from the floor by a series of rubber mountings. The alternator is driven through a flexible coupling consisting of two steel discs, one of which is fitted to the engine crankshaft and the other to the alternator shaft. The alternator was supplied by the Elliot Company, Jeannette, Pa., U.S.A., and is a 6,000-volt three-phase 50-cycle machine having an output of 1,000 kW. Excitation is supplied by the generator mounted above the main alternator, as shown in the illustration; it is driven from the camshaft gear train through an extension shaft and runs at the same speed as the alternator. The switchgear is situated on one side of the alternator and can be seen to the left of the illustration. It was supplied by Messrs. Ferguson, Pailin, Limited, Manchester, and includes circuit breakers for connecting the incoming

mains and the Diesel set to the 'bus-bars and separate circuit breakers for supplying two substations situated in the works. The engine is started by an electric motor fitted with a sliding pinion which engages a ring gear fitted to the alternator end of the crankshaft. Current for the starter motor is supplied by batteries stored in lockers outside the power-house and charged by a trickle-type charger.

The engine-exhaust gases are passed through a La Mont waste-heat boiler before being discharged to atmosphere, the hot water from the boiler being used to supplement the main factory supply. The boiler and exhaust trunking can be seen in the background to the left of the illustration. The exhaust system has been arranged so that, when required, the boiler can be by-passed and the exhaust gases discharged directly to the atmosphere. The fuel oil is stored in two 12,000-gallon cylindrical tanks situated approximately 50 yards from the power house. The fuel is transferred from the bulk-storage tanks to a ready-use tank, located in the power house, by electrically-driven gear-type pumps. The pumps are housed in a pump room alongside the bulk-storage tanks and are controlled by a float switch fitted to the ready-use tank.

The power house is exceptionally well laid out, there being ample room for dismantling and overhauling the engine. The heat exchangers for the lubricating oil and engine cooling water are mounted high up on one wall and all service pipes are painted in distinctive colours. The engine instruments, which are grouped neatly on a panel fitted to the end of the engine remote from the alternator include pressure gauges for all services and a tachometer; exhaust temperatures for each cylinder can be read on a remote-type pyrometer mounted on the wall of the power house. A noticeable feature is the facing of the interior walls of the power house with coloured glazed tiles; these give a pleasing appearance and enable the walls to be kept clean with the minimum of effort.

LAUNCHES AND TRIAL TRIPS.

M.S. "OUOLOF."—Single-screw cargo vessel, built by the Goole Shipbuilding and Repairing Company, Limited, Goole, for the Compagnie de Navigation Paquet, Boulevard des Dames, Marseilles. Main dimensions: 229 ft. 8 in. by 39 ft. 4 in. by 18 ft.; deadweight capacity, 1,840 tons on a draught of 14 ft. 2¾ in. Diesel engine of 810 brake horse-power supplied by Messrs. Mirrlees, Bickerton and Day, Limited, Stockport, Cheshire. Launch, February 28

M.S. "SALOUM."—Single-screw cargo vessel, built by the Goole Shipbuilding and Repairing Company, Limited, Goole, for the Société Navale de l'Ouest, 8, rue Auber, Paris. Main dimensions: 229 ft. 8 in. by 39 ft. 4 in. by 18 ft.; deadweight capacity, 1,840 tons on a draught of 14 ft. 2¾ in. Diesel engine of 810 brake horse-power supplied by Messrs. Mirrlees, Bickerton and Day, Limited, Stockport, Cheshire. Trial trip, March 12.

M.S. "SOUDAN."—Twin-screw cargo vessel, with accommodation for 12 passengers, built and engined by Messrs. Barclay, Curle and Company, Limited, Clydeholm Shipyard, Glasgow, W.4, to the order of the Peninsular and Oriental Steam Navigation Company, 122, Leadenhall-street, London, E.C.3. Main dimensions: 525 ft. by 67 ft. by 43 ft. to shelter deck; gross tonnage, 10,700. Two sets of Barclay, Curle-Doxford six-cylinder opposed-piston oil engines of 13,600 aggregate brake horse-power, to give a service speed of 18 knots. Trial trip, March 31.

S.S. "FRED. CHRISTENSEN."—Single-screw cargo vessel, with owner's suite, built by Messrs. John Readhead and Sons, Limited, West Docks, South Shields, to the order of Messrs. C. H. Sörensen & Sönner, Arendal, Norway. Main dimensions: 405 ft. 10 in. by 60 ft. by 37 ft. 6 in. to upper deck; deadweight capacity, about 8,000 tons on a draught of 24 ft. Fredrikstad double compound steam motor, built under licence by Messrs. John Readhead, with two Foster Wheeler water-tube boilers, built by Messrs. Richardsons, Westgarth and Company, Limited, West Hartlepool, developing 3,160 indicated horse-power with a service speed of 13 knots. Launch, April 7.

S.S. "LORD ANCASTER."—Single-screw trawler built by Messrs. Cochrane and Sons, Limited, Ouse Shipbuilding Yard, Selby, for the Lord Line, Limited, St. Andrew's Dock, Hull. Main dimensions: 175 ft. by 30 ft. 6 in. by 16 ft. Triple-expansion engine constructed by Messrs. Amos and Smith, Limited, Albert Dock Works, Hull. Launch, April 24.

S.S. "SIDI MABROUK."—Single-screw vessel with accommodation for 40 first class and 150 deck passengers, sheep and general cargoes. Built and engined by Messrs. J. Samuel White and Company, Limited, East Cowes, to the order of the French Government, for service between Mediterranean and North African ports. Main dimensions: 372 ft. 6 in. by 51 ft. by 27 ft. 10 in. to upper deck; deadweight capacity, about 4,000 tons on a draught of 23 ft. 8 in. One set of Parsons-type turbines with double-reduction gearing, producing a maximum of 4,600 shaft horse-power, with a speed of about 16 knots. Launch, April 24.

BOOKS RECEIVED.

Fractional Horsepower Electric Motors. What Kinds Are Available. How to Repair, Rewind and Reconnect Them. By CYRIL G. VEINOTT. Second edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 5 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 30*s.*]

Ferrous Metallurgical Design. Design Principles for Fully Hardened Steel. By JOHN H. HOLLOMON and LEONARD D. JAFFE. John Wiley and Sons, Incorporated, 440 Fourth-avenue, New York 16, U.S.A. [Price 5 dols.] Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 30*s.* net.]

Phénomènes radioactifs et Introduction à la Physique nucléaire. By PROFESSOR GEORGES GUEBEN. Editions Desoer, 21 rue Ste-Véronique, Liége, Belgium. [Price 280 Belgian francs]. Dunod, 92 rue Bonaparte, Paris (VIe). [Price 950 French francs.]

Bulletin de l'Association Technique Maritime et Aéronautique. No. 46. 1947. Firmin-Didot et Cie, 56, rue Jacob, Paris; and the offices of the Association, 1, Boulevard Haussmann, Paris (IXe). [Price 2,500 French francs, postage extra.]

Theoretische Elektrotechnik. Volume II. *Grundzüge der Theorie des Wechselstromkreises und des Einphasigen Transformators.* By DR. ING. KARL KUHLMANN. Verlag Birkhäuser, Basle, Switzerland. [Price 26·50 Swiss francs.]

The Industrial Environment and Its Control. By J. M. DALLAVALLE. Pitman Publishing Corporation, 2, West 45th-street, New York 19, U.S.A. [Price 4·50 dols.] Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 30*s.* net.]

Skin Protection in Industry: A Scientific Approach to an Aspect of Industrial Welfare. Rozalex, Limited, 10, Norfolk-street, Manchester, 2. [Free to approved applicants.]

The Amateur's Lathe. By LAWRENCE H. SPAREY. Published for the Drysdale Press, by The Harborough Publishing Company, Limited, Edward Buildings, Rutland-street, Leicester. [Price 12*s.* 6*d.*]

Automobile Chassis Design. By R. DEAN-AVERNS. Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1. [Price 15*s.* net.]

Introduction to Aerodynamics of a Compressible Fluid. By PROFESSOR HANS WOLFGANG LIEPMANN and ALLEN E. PUCKETT. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 4 dols.] Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 24*s.* net.]

Applied Electronics. By D. HYLTON THOMAS. Blackie and Son, Limited, 66, Chandos-place, Strand, London, W.C.2. [Price 7*s.* 6*d.* net.]

Géométrie Descriptive à Quatre Dimensions. Volume I. *Figures du Premier Degré. Définitions, Positions, Intersections.* Librairie Gauthier-Villars, 55, Quai des Grands-Augustins, Paris (VIe). [Price 200 francs.]

Applied Differential Equations. By PROFESSOR F. E. RELTON. Blackie and Son, Limited, 66, Chandos-place, Strand, London, W.C.2. [Price 20*s.* net.]

The British Electrical and Allied Industries Research Association. Technical Reports. No. F/T168. *Electrolysis and the Bond Strength of Reinforced Concrete.* By W. L. G. GENT and DR. G. MOLE. [Price 14*s.* net.] No. G/T204. *The Prospective Current-Arc Energy Relationship in Cartridge Fuses, Particularly for Currents at Which Operation is Inherently Difficult.* By H. W. BAXTER and M. T. CREE. [Price 3*s.* net.] No. L/T181. *Spontaneous Capacitance Fluctuations in Silvered Ceramic and Silvered Mica Capacitors.* By H. F. CHURCH. [Price 6*s.* net.] No. M/T94. *A.C. Harmonics Due to a Traction System Supplied by Mercury Arc Rectifier (Tests on the Euston-Watford Line).* By A. BUTTERWORTH and E. E. HUTCHINGS. [Price 5*s.* net.] Offices of the Association, 15, Savoy-street, Strand, London, W.C.2.

The College of Aeronautics, Cranfield. Report No. 8. *Note on the Velocity and Temperature Distributions Attained with Suction on a Flat Plate of Infinite Extent in Compressible Flow.* By A. D. YOUNG. Report No. 9. *On Source and Vortex Distributions in the Linearised Theory of Steady Supersonic Flow.* By A. ROBINSON. Report No. 10. *Bound and Trailing Vortices in the Linearised Theory of Supersonic Flow, and the Downwash in the Wake of a Delta Wing.* By A. ROBINSON and SQUADRON LEADER J. H. HUNTER-TOD. Report No. 11. *Application of the Linear Perturbation Theory to a Compressible Flow About Bodies of Revolution.* By A. D. YOUNG and DR. S. KIRKBY. Report No. 12. *The Aerodynamic Derivatives with Respect to Sideslip for a Delta Wing with Small Dihedral at Supersonic Speeds.* By A. ROBINSON and SQUADRON LEADER J. H. HUNTER-TOD. Report No. 13. *Assessment of Errors in Approximate Solutions of Differential Equations.* By PROFESSOR W. J. DUNCAN, F.R.S. The Librarian, The College of Aeronautics, Cranfield, Buckinghamshire. [Strictly limited issue: copies free to approved firms, Institutions and official bodies.]

PERSONAL.

MR. CECIL BENTHAM, C.B.E., M.I.C.E., M.I.Mech.E., M.Inst.T., retired on May 3 from the chairmanship of Messrs. Henry Simon Limited, Cheadle Heath, Stockport, which position he has held for 14 years. Mr. Bentham's successor as chairman is Sir Patrick Hamilton, Bt.

LIEUT.-COMDR. RICHARD FAIRTHORNE, R.N. (ret.), M.I.E.E., A.M.I.Mech.E., has been elected President of the Institution of Engineering Inspection. MR. J. A. HARDING, A.M.I.Mech.E., and MR. A. VERNON WATSON, A.M.I.P.E., A.I.Mech.E., have been elected vice-presidents.

MR. S. E. TAYLOR, D.S.C., M.A. (Cantab.), the President-elect of the Institution of Mining and Metallurgy, Salisbury House, Finsbury-circus, London, E.C.2, will be inducted at the annual general meeting of the Institution, to be held on May 20.

MR. W. LYONS, chairman and managing director of Jaguar Cars Limited, Coventry, has been appointed a vice-president of the Society of Motor Manufacturers and Traders.

MR. C. H. BAILEY, B.Sc., has been appointed chairman of the Mining Committee of the Royal Institution of Chartered Surveyors in succession to MR. A. R. THOMLINSON, who has relinquished the position owing to ill health.

MR. HARRY HILL has retired from the position of manager of the Erith Works of British Insulated Callender's Cables Limited. He joined the firm in 1906 and became works manager in 1940.

MR. R. F. HIELD has resigned his appointment as assistant works director for southern factories with Messrs. Crompton Parkinson, Limited, to join the staff of Messrs. Veritys Limited, as general manager, at Plume and Victoria Works, Aston, Birmingham, 6.

COLONEL R. B. EMERSON, C.I.E., O.B.E., M.Inst.T., lately Chief Commissioner of Railways in India, has joined the boards of the associated companies in the Dowsett Group. He has been appointed deputy chairman of Dowsett Engineering Construction, Limited; Dow-Mac (Construction) Limited; Dow-Mac (Plant and Transport) Limited; Dow-Mac (Quarries) Limited; Dow-Mac (Products) Limited; and joint managing director of Brooke Marine Limited.

MR. E. H. BALL has been appointed to the board of the Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester, 17, as from May 4.

DR. R. LESSING has been elected chairman of the Technical Committee of the Executive Council of the National Smoke Abatement Society, Chandos House, Buckingham Gate, London, S.W.1.

MR. B. W. METHLEY has now retired from the position of chief chemist of the Steel, Peech and Tozer branch of the United Steel Companies, Limited, Sheffield. He first joined the staff of Messrs. Steel, Peech and Tozer 47 years ago and will continue to serve the Central Research and Development Department of the United Steel Companies in a consultative capacity.

MR. S. C. BRITTON, M.A. (Cantab.), has relinquished his position in the Research Department, London Midland Region, British Railways, to join the staff of the Tin Research Institute, Fraser-road, Greenford, Middlesex.

MR. CHARLES T. MORRALL, who was associated for many years with International Combustion Limited, and has been general manager of Autocontrol Boilers, Limited, for the past few years, has now joined Messrs. Frederick Kay (Engrg.) Limited, 61, Northdown-street, King's Cross, London, N.1, as director of sales.

MR. ALAN R. BAILEY has recently taken up the post of senior lecturer in metallurgy at the Constantine Technical College, Middlesbrough.

The Board of Trade announces that MR. A. G. C. DEUBER, United Kingdom Trade Commissioner, Grade II, has left Nairobi for South Africa on transfer to a post in the Union. His successor in East Africa is MR. G. T. DOW-SMITH, who served formerly at Delhi and Karachi.

THE INSTITUTION OF HEATING AND VENTILATING ENGINEERS, 75, Eaton-place, London, S.W.1, announce that their new telephone number is SLOane 3158.

THE ENGLISH ELECTRIC COMPANY LIMITED, Aircraft Division, will close down their offices in Corporation-street, Preston, Lancashire, this afternoon, Friday, May 14, and will re-open them at a new address, namely, Warton Aerodrome, near Preston, Lancashire, on Thursday morning, May 20. The new telephone number is Freckleton 371.

RELAYING RAILWAY TRACK.—A 2,090-yard section of the London Midland Region down main line between Chesterfield and Clay Cross was recently relaid in six hours. The old track was removed, 475 tons of ballast were spread to raise the track 2 in., and 105 pre-fabricated lengths of track were laid by cranes, and fish-plated. Allowing for interruptions due to traffic passing on adjacent lines, the net working time was five hours.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—The uncertainties associated with scrap supplies continue to render difficult the organisation of uninterrupted outputs at the local steelworks, but a slight improvement in the deliveries of raw materials has allowed production to be re-established on a capacity basis, and the furnaces which had been idle in Lanarkshire are again in operation. The spade-work in connection with the drive for increased collections of domestic scrap is practically completed, and good results are already appearing. Scrap merchants are giving strong support to the campaign, while a quicker turn-round of scrap accruing from operations at steel-consuming centres is also noticeable. Urgent appeals have been made to the authorities for improved imports of scrap from Germany, shipments of which recently have been intermittent and of no great volume. At the moment, Messrs. Stewarts and Lloyds, Mossend, are producing steel slightly in excess of their existing tube-mill capacity, and for the first time since they transferred their universal plate mill to Corby, in 1932, they are again making ingots, which, until their new tube mill is completed at Mossend, are being rolled into plates at Colvilles' Motherwell works. Provided sufficient scrap can be made available to keep Scottish production at the equivalent annual rate of 2,115,000 tons, achieved in the first quarter of the year, Scottish makers are confident that fears expressed regarding a possible shortage of shipbuilding steel will prove to be unfounded. Despite the increasing difficulty in obtaining import licences for steel products in European countries, Finland, Sweden, Denmark and Holland are still making inquiries for large tonnages of steel, with a noticeable preference, in the case of the two last-mentioned countries, for shipbuilding materials.

Scottish Coal.—Confronted by a deficit of some 400,000 tons, which accumulated during the first 17 weeks of the year, the Scottish miners made a fairly satisfactory restart after the holiday. There was a complete absence of stoppages due to labour troubles, and attendances were almost equal to the average for a normal working day. Coke ovens maintained maximum production without experiencing any major fuel problem. There was some shortage in consumer supplies last week, while outputs at the pits were building up, but the general reserve position was adequate to overcome temporary delays in deliveries. Export business has continued on steady lines. Regular shipments have been arranged from Methil for Sweden, Finland and Denmark, and from Ayrshire ports to Eire.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

Welsh Coal Trade.—Mr. A. Davies, the area President, told the delegates at the annual conference of the South Wales area council of the National Union of Mineworkers, held in Cardiff last week, that since nationalisation the downward trend in manpower in the industry had been arrested. On vesting day the number of men engaged in the South Wales mines was 692,401 and to-day it was 723,234. More had to be done to make the mines attractive to young men. Output per man-shift had increased to almost pre-war level and attendances at the mines were better than for many years. He urged the miners to accept the Coal Board's policy of closing uneconomic pits. The conference was strongly critical of what it described as unnecessary appointments by the divisional Coal Board. It was contended that the method of appointment was undemocratic since there were no advertisements for applicants, which led to the appointment of incompetent persons occupying responsible positions. Such appointments added to the economic burden carried by the industry. It was stated that the national executive of the union was preparing a report from all divisions on the matter, for discussion with the N.C.B. Busy conditions have continued on the steam-coal market throughout the week. As a result of recent activity, the export trade was on busier lines and although there was an active demand, the amount of fresh business that could be entertained was strictly limited. Practically all the coal that could be spared for immediate shipment abroad had been allocated, but the requirements of the inland section were very heavy and prevented any substantial expansion in export business. Bunker business was active and patent fuel and cokes were in brisk request, but supplies were not easy to secure.

Swansea Steel-Sheet Industry.—The market report issued by the Incorporated Swansea Exchange states that, last week, home consumers of tin-plate continued to cover their requirements for the current quarter, and the sales made were much in excess of a week's production. Recent activity in the export market, however, has not been maintained and a reduced number of orders were booked during the week. Steel sheets continue to be in insistent demand and there is no relaxation in the call for iron and steel scrap.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The production of steel increases steadily but supplies are not yet sufficient to cover the requirements of users. Some concern is expressed at the decision of the Government of India to impose a protective tariff on high-grade steels from Sheffield, including high-speed, stainless, heat-resisting and some other alloy steels. The recommendation of the Tariff Board was accepted in spite of a reasoned protest from Sheffield, and the duty is to remain in force until March 31, 1950. It is also recommended that import control should be continued, so that an order is not released for special steels from Sheffield unless Indian manufacturers cannot supply, or the demand cannot be met from surplus war stocks. Sheffield steel firms are making progress with their schemes of re-organisation and re-equipment. Apart from purely armament sections, there is continued activity in the specialised manufacture of oil-well equipment, heavy castings for locomotives and rolling stock, and heavy machine tools. Good progress is being continued in the manufacture of American-type excavators and other equipment for opencast mining. Tool factories are still very busy, but have now reached a stage of re-equipment and re-organisation that permits much quicker deliveries to be made than was customary a short time ago.

South Yorkshire Coal Trade.—Some unofficial disputes have checked production which was beginning to improve again, as is usual before a statutory holiday. Allocations of locomotive fuel have been increased to meet the requirements of holiday-train traffic. At the same time, fuller allocations of best steams and gas coal have had to be made to meet export commitments. More outcrop coal is being produced, and is directed to all sections of the market. House coal is in ample supply but the quality is variable. More coking coal is being supplied to meet the heavy and insistent demands of the coke works.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—North-East Coast iron and steel manufacturers are still producing large quantities of materials, but the total distributable tonnage is not sufficient for the consumers' demands. The new delivery authorisation system, however, appears to be working smoothly in various branches of the steel industry. The output of the Cleveland ironstone mines still falls short of 20,000 tons a week, but imports of foreign ores are on a very high level. Larger allocations of coke for the blast-furnaces would be much appreciated. The scarcity of iron and steel scrap is rather less acute than it has been for some time, but scrap is still wanted in considerably larger quantities than are coming forward. Imports from Germany are still much below expectations and unless supplies of coke and imported scrap expand in the near future there will be considerable difficulty in maintaining the heavy steel production at its present level.

Foundry and Basic Iron.—The pressure for better deliveries of foundry pig-iron continues. Consumers are more than ever dependent on supplies from the Midlands and while parcels from that area show some improvement they are still below current needs. There seems little likelihood of a resumption in the make of No. 3 Cleveland pig, but an ample supply of coke would enable idle blast-furnaces to be re-kindled for the production of iron suitable for the foundries. Basic-iron makers are providing sufficient tonnage for their own steel furnaces, but, as has been the case for some time past, have no surplus for consumption elsewhere.

Hematite, Low Phosphorus and Refined Iron.—Users of East-Coast hematite have to be content with supplies that are hardly sufficient for their requirements, though they are still calling for deliveries on a scale that would enable their depleted stocks to be built up. Outputs of low-phosphorus grades of iron are quickly taken up and all available quantities of refined iron are being steadily absorbed.

Manufactured Iron and Steel.—Branches of industry turning out semi-finished and finished iron products are busily occupied and have sufficient work in hand to keep them actively engaged over the present delivery period; steel firms still have commitments equal to their full capacity outputs. Steel semies are reaching users in rather larger quantities from home producers, but imports of Continental material are still meagre. Re-rollers are demanding larger parcels of billets and sheet bars, and finished descriptions of steel are in strong request. The demand for black and galvanised sheets absorbs the outputs as they become available; even to shipyards, deliveries of essential supplies are limited, and railways, are not obtaining the whole of their requirements, owing to the export commitments of the rail mills.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

ROYAL STATISTICAL SOCIETY.—*Industrial Applications Section:* Wednesday, May 19, 6.30 p.m., Newcastle Chemical Industries Club, 18, Lovain-place, Newcastle-upon-Tyne. Discussion on "Experiments in Industrial Chemistry," to be opened by Mr. K. A. Brownlee. Thursday, May 20, 7 p.m., William Newton School, Norton, Stockton-on-Tees. Discussion on "The Use of the Factorial Experiment for Investigating Chemical Processes," to be opened by Mr. K. A. Brownlee.

INCORPORATED PLANT ENGINEERS.—*Western Centre:* Wednesday, May 19, 7.15 p.m., Grand Hotel, Bristol. "Fans and Fan Appliances," by Mr. K. L. Whitaker. *Liverpool Centre:* Thursday, May 20, 7.30 p.m., Grosvenor Museum, Chester. Film on "Chain Grate Stokers." *Glasgow Branch:* Tuesday, May 25, 7 p.m., Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow. "Power Transmission Problems and the Use of Suitable Couplings," by Mr. C. W. Chapman.

INSTITUTION OF MINING AND METALLURGY.—Thursday, May 20, Geological Society, Burlington House, Piccadilly, W.1. 4 p.m., Annual General Meeting, open to members and associates only. 5.15 p.m., Presidential Address, by Mr. S. E. Taylor.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Measurements Section:* Friday, May 21, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Lecture on "Great Personalities in the Fields of Electrical and Magnetic Measurements," by Professor J. T. MacGregor-Morris. *Scottish Centre:* Friday, May 21, 7.30 p.m., Training College Hall, Park-place, Dundee. Faraday Lecture on "Electricity and Everyman," by Dr. P. Dunsheath. *London Students' Section:* Wednesday, May 26, 7 p.m., Savoy-place, Victoria-embankment, W.C.2. Annual General Meeting.

ELECTRODEPOSITORS' TECHNICAL SOCIETY.—Monday, May 24, 5.30 p.m., Northampton Polytechnic, St. John-street, Clerkenwell, E.C.1. "Continuously Electroplated Steel Strip and Sheet," by Messrs. A. Smart and F. H. Smith.

SWANSEA AND DISTRICT METALLURGICAL SOCIETY.—Tuesday, May 25, 6.30 p.m., Royal Institution, Swansea. Annual General Meeting.

SOCIETY OF INSTRUMENT TECHNOLOGY.—Tuesday, May 25, 6.30 p.m., Manson House, Portland-place, W.1. Annual General Meeting. "Proposed System in Instrumentation Symbols," by Mr. J. K. Burkitt.

ROYAL AERONAUTICAL SOCIETY.—Thursday, May 27, 6 p.m., Institution of Civil Engineers, Great George-street, S.W.1. Wilbur Wright Lecture on "Size in Transport," by Mr. A. Gouge.

INSTITUTION OF ENGINEERING DRAUGHTSMEN AND DESIGNERS.—Friday, May 28, 7 p.m., The Royal Society of Arts, John Adam-street, W.C.2. "Three-Dimensional Engineering Drawing," by Mr. W. E. Walters.

ROYAL SANITARY INSTITUTE.—The annual "Health Congress" of the Royal Sanitary Institute will be held, this year, from May 24 to 28, at Harrogate. The attendance is expected to be about 2,400 and will include delegates from 29 Dominion, Colonial and foreign Governments and municipalities, and from 18 Government departments and 900 local authorities in the British Isles. Among the sectional meetings and conferences to be held are several for engineers and architects, sanitary inspectors, surveyors and specialists in housing and town planning. Further particulars may be obtained from the secretary of the Institute, 90, Buckingham Palace-road, London, S.W.1.

DAVY-UNITED GROUP APPRENTICE-TRAINING SCHEME.—We have received from Messrs. Davy and United Engineering Company Limited, Park Iron Works, Sheffield, 4, a brochure entitled "Engineering for the Metals and Sugar Industries." This describes and illustrates the apprentice-training scheme which the company have recently launched in conjunction with the other two firms in the group, namely, Messrs. Davy and United Roll Foundry, Limited, Billingham, and Messrs. Duncan Stewart and Company, Limited, Glasgow. The contents are divided up into a number of chapters bearing such headings as the trade apprentice, the student apprentice, the graduate apprentice, the vacation apprentice, promotion from one group to another and contemporary education while learning. In all cases the most detailed information is given and these data are likely to answer all questions put by would-be apprentices or their parents. Numerous reproductions of photographs of rolling mills, forging presses, plate-shearing machines, steam hammers, sugar machinery and other plant and of views taken in the various shops of the Davy-United Group of firms are included.

EXHIBITS AT THE BRITISH INDUSTRIES FAIR, BIRMINGHAM.

(*For Description, see Page* 461.)

FIG. 20. "STACASCOOP" TRUCK; MESSRS. I. T. D. LIMITED.

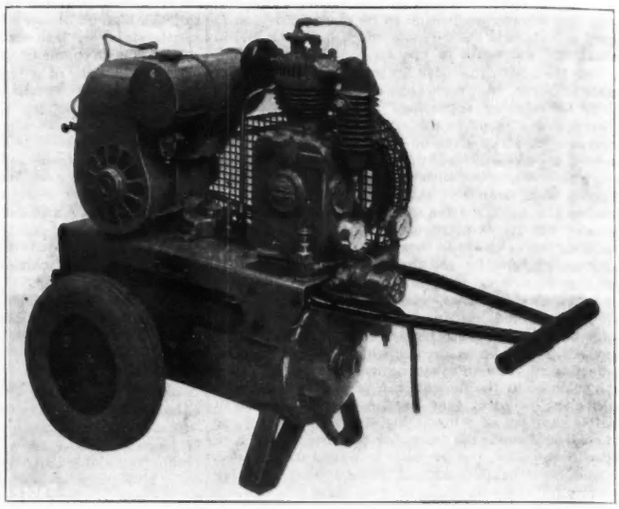


FIG. 21. AIR COMPRESSOR FOR SPRAY-PAINTING; MESSRS. H. E. C. COMPRESSORS AND ENGINES, LIMITED.

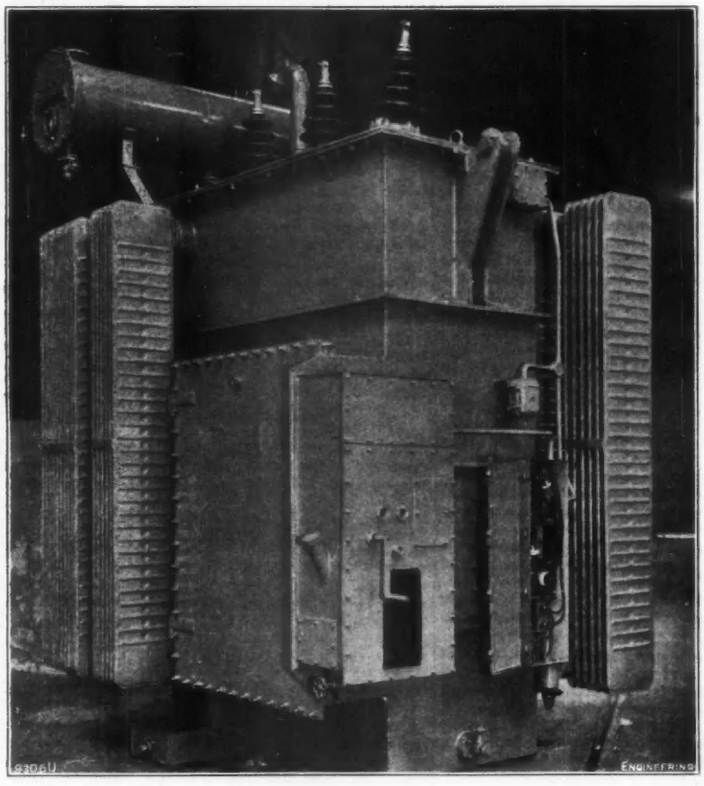


FIG. 22. 1,000-KVA 33/11-KV TRANSFORMER AND TAP CHANGER; MESSRS. FERRANTI, LIMITED.

FIG. 23. JEANS' SEED CONDITIONER; MESSRS. FERRANTI, LIMITED.

CHEMICAL RESEARCH LABORATORY, TEDDINGTON.—The Chemical Research Laboratory, Department of Scientific and Industrial Research, Teddington, Middlesex, is again holding a series of open days in July. As was the case last year, representatives of industry, Government departments, universities and technical colleges will be invited to inspect the Laboratory and to view the work in progress. There will be three sessions, namely, the afternoon of July 1 and the morning and afternoon of July 2. In view of the interest expressed, it has been decided to issue invitations to industry on an increased scale. The Director, Dr. R. P. Linstead, C.B.E., F.R.S., will be glad to receive applications from industrial firms wishing to send representatives. The five main branches of research concern the corrosion of metals, high polymers and plastics, coal-tar constituents, organic intermediates, and inorganic chemistry.

NEW COMPANY FOR GLASS-BULB MANUFACTURE.—A new company, entitled Glass Bulbs, Limited, has recently been registered with a capital of 1,000,000*l.*, which will be subscribed equally by the British Thomson-Houston Company and General Electric Company. This concern proposes to build a new factory at Harworth, near Doncaster, where two "Ribbon" machines of the type developed by the Corning Glass Company, of Corning, New York, will be in operation by the end of 1949. These machines have a potential capacity of over 400 million lamp and valve bulbs per annum; and it is to be the policy of Glass Bulbs, Limited, to make them freely available to all manufacturers in the lamp and valve industries. It should thus be possible to develop a considerable export trade in bulbs and for the older factories of the two firms, which, since 1940, have found it difficult to meet the growing demand, to be devoted mainly to making domestic glassware.

ENGINEERING.

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and any other publication bearing a similar title.

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ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for inserts, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2¼ in. wide. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 8*s.* for the first four lines or under, and 2*s.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 24*s.* per inch. If use is made of a box number the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33⅓ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

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ENGINEERING

FRIDAY, MAY 14, 1948.

VOL. 165. No. 4294.

GERMAN SHIPBUILDING IN THE WAR YEARS.

IN Germany, even more than in Britain, during the war years 1939 to 1945, naval shipbuilding had first call upon the resources of the shipyards; to mention one branch only (but the most important one to the German war effort), nearly 1,100 submarines were constructed, according to the paper given by Constructor Commander J. F. Starks to the Institution of Naval Architects two months ago. Obviously, therefore, only a limited capacity could have been available for the construction of other tonnage, and mercantile shipbuilding would have been forced to a virtual standstill in any case, so long as the submarine programme retained its high priority. In fact, of course, Germany could have had little need for a large fleet of ocean-going merchant ships while the war at sea was being prosecuted with vigour; except for the requirements of an invasion of Britain, coastal craft, if in sufficient numbers, could meet all the German needs for "short-sea" transport, and there was a considerable reserve of these available in the ports of the overrun European countries. Moreover, the shipyards of those countries could be used to build more, unless Allied air attacks made such sustained effort impracticable; and they were so used to some extent, although under conditions of great and increasing difficulty.

Such mercantile shipbuilding as was undertaken in the German shipyards, however, presents features of some technical interest; though not so pronounced a novelty as might have been expected from the prominence given to German studies in naval architecture, before the war, in the British professional institutions and technical Press. In some respects, undoubtedly, German pre-war progress in naval architecture and marine engineering was notable; but, regarded in retrospect, it can be seen now to have been notable rather for readiness to experiment, and to give full (almost over-full) publicity to the results of experiment, than for the amount of its real advancement. Some very ingenious novelties were introduced from time to time, especially in the domain of marine engineering, and several of them achieved a measure of success; but there is at least an element of doubt whether the same or a greater success might not have been achieved more economically, in the long run, if a corresponding effort had been directed to improvement along what may be termed "orthodox" lines. There was much surprise when the United States authorities declined to take over the Europa as reparations because she fell short of their statutory requirements to ensure safety of life at sea and could not be brought into line with those requirements without a drastic and uneconomic reconstruction; but the rapidity with which she filled and sank in Le Havre, after the great gale of December, 1946, carried her into collision with the wreck of the liner Paris, amply confirmed the wisdom of the decision.

The British Intelligence Objectives Sub-committee (or, more briefly, "B.I.O.S.") and the associated services of the other Allied countries, made a fairly exhaustive study of German shipbuilding and marine engineering, and have prepared a large number of reports. Many are of considerable technical interest, but the mere volume of the information gathered is a bar to its widespread dissemination in its original form. This disability, of course, is not peculiar to the reports on shipbuilding and marine engineering, and the Sub-committee have been engaged for some time, therefore, in preparing digests which will present the main features in a more compact form. The first of this series dealt with the petroleum and synthetic-oil industry of Germany and the second, now available,* covers shipbuilding and marine engineering. It has been prepared by Mr. F. C. J. Jacob, of the staff of the British Shipbuilding Research Association, and summarises not only some 80 sectional reports already published, but also a number of others still unpublished and various German documents collected in the course of the B.I.O.S. inquiries.

Practically the whole of the report deals with mercantile work, the principal exceptions, of interest to those concerned with merchant shipping, being the three high-speed tankers, of 22,000 shaft horse-power, which were built to supply naval surface ships and submarines; these three ships were allocated to the United States, Britain and Russia, respectively, as reparations. It appears that, during the war years, construction was begun on only one large passenger ship, this being the Vaterland, of 36,000 tons, laid down at the Blohm and Voss yard, and designed to have high-pressure steam machinery of 44,000 shaft horse-power and a speed of 24 knots. The eight Benson forced-circulation boilers were to work at 950 lb. per square inch, with a steam temperature of 877 deg. F., and the drive was turbo-electric. The hull construction was a combination of welding and riveting. The vessel was launched, but was bombed, set on fire, and eventually sunk in dock. The Deschimag organisation had designs in hand for an Atlantic liner, larger than the Queen Elizabeth, to have machinery of 300,000 h.p. on five shafts and a speed of 36 knots to 38 knots; but apparently this vessel did not progress beyond the stage of model tests.

The principal programme of merchant-ship building was that of the Hansa-type ships, of which three sizes were planned, of 3,000 tons, 5,000 tons and 9,000 tons, respectively; of these, 52 of the 3,000-ton ships were delivered, and three of 9,000 tons. The number of 5,000-ton ships is not stated. The 3,000-ton size had Capus boilers with a Scotch auxiliary boiler, and were fitted with superheaters, economisers and air heaters. The main engines were of the Lentz type, with Bauer-Wach exhaust turbines. Apparently, the use of Lentz engines was dictated by considerations of production, the available capacity for the construction of turbines and gearing being limited. Some of the 9,000-ton ships had hand-fired water-tube boilers and others had stoker-fired boilers. Some large cargo vessels were built in the John Cockerill yard at Antwerp for the North German Lloyd line. They had a deadweight capacity of 12,000 tons and the unusual feature, for such ships, of triple screws and a speed of 18½ knots. The engines were two-cycle single-acting Sulzer Diesels of 3,900 h.p. each on the wing shafts and 4,500 h.p. on the centre shaft. The

* *Shipbuilding and Marine Engineering in Germany During the Period* 1939-45. B.I.O.S. Overall Report No. 2. H.M. Stationery Office, York House, Kingsway, London, W.C.2. [Price 6*d.* net.]

wing shafts were fitted with mechanical clutches, so that these engines could be disconnected and the centre engine used alone for cruising.

The very extensive use of concrete by the Germans in the construction of fortifications may be one reason why they did comparatively little in the way of building concrete ships, but the programme included several vessels of considerable size—two 3,000-ton tankers, one of 3,400 tons, and a cargo vessel of 3,700 tons, as well as some large lighters; but not all of these were completed. Welding was used extensively in submarine construction, but in various respects German shipyard practice lagged behind that of Britain and the United States; for instance, there was little automatic welding. In cargo vessels, welding was used mainly for butts in shell plating, decks, tank tops, etc. The finished welds were inspected by X-rays, and it is reported that the quality of the work was good.

On the subject of propelling machinery, the report contains some items of considerable technical interest, though they are dealt with very briefly—a feature, indeed, which characterises the whole of the report. Before the war, German marine engineers were acquiring a reputation for being extremely progressive, largely on the strength of their adoption of Benson forced-circulation boilers. Now it appears that they encountered such difficulties in the operation of such units that, in the later years of the war, they reverted to natural circulation. La Mont boilers were used extensively in both naval and mercantile vessels, and although the report states that the German Navy found them unsatisfactory because the nozzles became choked and there was a formation of scale "when the vessels lay in harbour," it must be conceded that the German destroyers, at any rate, seldom seemed to be short of steam when a sustained burst of high speed was required at sea. The pressures used with La Mont boilers had ranged up to 1,210 lb. per square inch and the steam temperature to 932 deg. F., but before the war it became the practice to limit steam pressures to 1,000 lb. per square inch and the temperature to 850 deg. It is remarked that the workmanship of the naval boilers was notably better than in the mercantile types.

Several types of high-pressure natural-circulation boiler were in use, the Wagner boiler being most favoured for high powers. This was the type fitted in the Scharnhorst and Gneisenau, and also in the high-speed tanker Nordmark, one of the three supply ships for submarines, previously mentioned. The report summarises the results of some interesting model experiments on boilers of this type to investigate, *inter alia*, the effect on the circulation of rapid fluctuations in steam pressure. In some of the experiments, tubes were deliberately caused to burst; investigation of the effects, it is stated, was of great value in studying the numerous failures of tubes in the high-pressure boilers of destroyers and torpedo boats. A point of interest, also noted in connection with the battleship Gneisenau, was that her condenser tubes (of aluminium brass) were perfectly clean after seven years' service, a condition which was attributed to the practice of limiting the speed of flow of the circulating water through the tubes to a maximum of 360 ft. per minute; it was found, the report states, that speeds in excess of this figure caused de-aeration, salt deposit on the tube walls, and harmful oxygen formation.

Many other matters of interest are contained in the report, not only in connection with such major questions as the design of Diesel engines, and of gas turbines for marine propulsion—on which much research was done, though no units were actually completed—but also in matters of detail. Stainless-steel propellers, originally adopted because of the scarcity of bronze, were found to have twice the life of bronze propellers. Alternating current was preferred for electric drives, and it is reported that, in turbo-electric ships, the ability to reverse with alternating current overcame the considerable trouble experienced with turbine blades, attributed to manœuvring problems. In general, it may be said that the summary is a useful pointer to the many features of technical value in the full reports, but many readers of it are likely to wish that it had been planned on more generous lines, comparable to the report on the German oil industry.

OIL PRODUCTION AND CONSUMPTION.

THE annual peace-time consumption of petroleum in the United States is about 450 gallons per head of population; the corresponding figure for Great Britain is 80 gallons; that for the Soviet Union 50 gallons, and for the world as a whole, excluding the United States, 15 gallons. Consumption is everywhere tending to increase. The growing demand is due not only to the phenomenal development in the use of the motor vehicle for both passenger and commercial road transport and the continually increasing importance of the Diesel engine at sea; rail traction, in which the Diesel engine is now taking a position of importance, and mechanical farming, of which so much is heard, both represent heavy demands on oil supplies. In the United States, important quantities of petroleum are also being used in the synthetic-rubber industry.

In the main, these various developments have a sound economic basis. The ever-increasing employment of the commercial road vehicle is due to the practical convenience of door-to-door delivery and not in any way to prejudice against rail transport. An economic basis, however, must involve an economic cost and as a long-range speculation it may be asked if this growing world dependence on natural petroleum can continue indefinitely. "Petroleum is now being used at such a rate in relation to its total amount in the earth's crust that its complete exhaustion is, from a geological viewpoint, alarmingly imminent." Leaving the question of "complete exhaustion" to a later generation, it appears possible that the increasing demand on diminishing resources may result in considerable increase in costs; the price of articles in short supply tends to rise. At the present time, there is no indication of any check to the use of petroleum or its products in any field of application, but if costs become sufficiently great some of the present users may find that their activities have become commercially unprofitable.

There is evidently some alarm in the United States about the oil situation, and the House of Representatives Armed Services Committee has suggested that nation-wide oil rationing may be necessary unless voluntary efforts to lessen demands are effective. In this country, the practice of rationing and controls has become a commonplace of everyday life, and petroleum and its products occupy a prominent position in the list of rationed articles. This particular control, however, is mainly imposed as a correcting factor in international finance and not from any bearing on the question of the exhaustion of supplies. The suggestion of the House of Representatives Committee, on the other hand, probably reflects an uneasy feeling that the United States is not only approaching the time when it will cease to be the world's largest producer, but that it may ultimately have to depend to a very considerable extent on supplies from other countries.

No useful opinion can be expressed about the likely outcome of voluntary efforts to lessen demands in the United States, but, it may be found that the price mechanism will ultimately form an effective control. As stated in the earlier article referred to above, 90 per cent. of the rail locomotives now on order in the United States are of the Diesel-engine type. The reason for this is that these machines are able to spend a larger proportion of their time in effective service than steam locomotives, require much shorter periods in preparation for the road, show lower maintenance costs and probably save man-power. Some of these considerations no doubt also determined the conversion of the Dover-Dunkirk channel-ferry steamers from coal to oil burners. Both these matters rest fundamentally on an economic basis, and if oil fuel becomes sufficiently expensive, or of such scarcity as to interfere with regular operation, it will cease to be commercially profitable. There is no reason why the Diesel locomotive should replace the steam locomotive and in as far as it may ultimately prove too expensive a luxury it will cease to do so. It is very possible that some, or many, of the changes to liquid fuel have been dictated by a desire to save man-power and simplify and ease the work of operators. These are legitimate objects, but cannot be permanently attained on unsound lines. If the present tendency to ease the tasks of labour and reduce its hours of work ultimately prove uneconomic from the point of view of national welfare (not from that of shareholders' dividends) it cannot endure. Ultimately, men always do what they have to do.

A review of the world position in relation to petroleum supplies was given by Professor Kirtley F. Mather, of Harvard University, in a lecture delivered at the British Association meeting in Dundee, last autumn, and printed in the January issue of *The Advancement of Science*. The quotation about the exhaustion of supplies which is given above is from Professor Mather's lecture, but taken by itself is not a fair summary of his assessment of the present position. It represents the long-term view, but on the shorter outlook on which mankind operates "it would appear that world petroleum reserves are quite adequate to meet world needs for half or three-quarters of a century to come." The first oil well was drilled in the United States in 1859, and up till January 1, 1947, 30 thousand million barrels of oil were produced in the country out of a world total of 52 thousand million barrels. The most recent estimates place the proved reserves of the world at 70 thousand million barrels and as total consumption is approaching a figure of three thousand million barrels a year, simple arithmetic suggests that supplies will be exhausted in 23 years. Professor Mather pointed out that this gloomy picture did not represent the true state of affairs, as proved reserves are only a fraction of actual reserves, but whether that fraction is one-half or one-tenth is a matter of serious moment. Considering the United States in particular, Professor Mather pointed out that the curve of proved reserves rose steeply from 1936 to 1939, and then showed a definite tendency to level off, and he estimated that it will begin to fall after 1950.

Oil sources have been surveyed more extensively in the United States than in any other country. The number of exploratory holes drilled increased from 2,700 in 1938 to 5,400 in 1946, but the number of new productive fields discovered has decreased each year since 1943 and it is thought that nearly all large oil pools have now been located, "with rare exceptions only small pools containing only a few million barrels await future discovery." Some extension of the field of exploitation may be obtained by drilling in the submerged Continental shelf. The shore line has no necessary relation to the occurrence of underground oil and there is reason to believe that reserves exist below the waters of the Gulf of Mexico. Oil wells are now operated in shallow water in Lake Maracaibo in Venezuela, but a similar operation in the exposed waters of the Gulf of Mexico would present formidable engineering problems. Professor Mather thinks that the search for oil in the Continental shelf may confidently be expected to add a few thousand million barrels to American reserves, but at best will only postpone by a few years the time when American production will lag far behind American consumption. He added that this under-sea winning of oil was an expensive process, which raises the point taken up in the earlier part of this article. If petroleum products become too expensive, some of the services for which they are employed, but are not essential, will be changed over to other methods, and demand will decrease.

In view of the political and financial interest being taken by the United States in Far Eastern oil sources, it may be expected that in the not very distant future substantial proportions of the consumption of that country will be imported, but this is likely to be supplemented by synthetic fuels. Experimental work on a semi-commercial scale is now being undertaken for production by hydrogenation, the Fischer-Tropsch process, and the distillation of shale. In connection with these alternative sources of liquid-fuel supply, Professor Mather states that "in the United States alone, there is enough oil-shale and coal available to provide the equivalent of two thousand million barrels of crude oil each year for at least a thousand years."

NOTES.

PRODUCTION OF RADIOACTIVE ISOTOPES AT HARWELL.

ALTHOUGH the production of radioactive isotopes at Harwell has naturally not reached the scale of the American plant at Tennessee, of which some particulars were given on page 447, *ante*, the Ministry of Supply is able to report considerable progress. The monthly production of radio-isotope samples reached 120 in March of this year. Of these, one-third was used at Harwell, the remainder being distributed to hospitals and research laboratories in various parts of the country. Isotopes of about 30 different elements have been made so far, but, owing to the low neutron intensity of the graphite low-energy experimental pile, the radioactive strength of various of the isotopes is very small. The new pile at Harwell is expected to come into operation this summer, when isotopes in much larger numbers and of greater strength will be produced. It is expected that the output will be sufficient to meet the demands of all research workers in Great Britain. Packing and distribution will be carried out by the Radiochemical Centre at Amersham. Radio-sodium is the isotope which has been prepared in the greatest quantities; as it has a half-life of only 14 hours it could not have been obtained from America. It is used both for research work and for the diagnosis of vascular diseases in hospitals. The first radio-isotope was sent out on September 28, 1947, a delivery of radio-iodine being made to the Medical Research Council for an operation at a Liverpool hospital. Figures of the total production of specimens of radioactive isotopes at Harwell, from September, 1947, to March, 1948, were, for the seven months covered, respectively, 17, 42, 42, 34, 76, 88 and 120. It is stated that radioactive isotopes sent out from Harwell are packed and sealed in such a way that, in the event of an accident to the carrying vehicle, no radioactive material would be released; but particulars of the method of packing have not been given. American practice is to carry the isotopes in stainless-steel cylinders protected by lead sheaths and mounted in a strong wooden box.

IRON AND STEEL INSTITUTE.

The seventy-ninth annual general meeting of the Iron and Steel Institute concluded with a members' luncheon, held at the Dorchester Hotel, Park-lane, on Thursday, May 6. The toast of the "Iron and Steel Institute and Industry" was proposed by Sir Oliver S. Francks, K.C.B., C.B.E., Ambassador-designate to the United States, who stressed the value of the Institute as a channel for technical education. One of the functions of the Iron and Steel Institute was to encourage and foster research in the chemistry and physics of ferrous metallurgy, from the university-laboratory stage into the practical industrial field. In responding to the toast, Sir Andrew McCance, D.Sc., F.R.S., the President, said that the foundation of the Institute had followed closely after the discoveries of Bessemer and other pioneers of the steel age, and that such institutes could only continue to exist where the free interchange of ideas was possible. The toast of the guests was proposed by Lieut.-Colonel Sir John Greenly, K.C.M.G., C.B.E., an honorary vice-president of the Institute, and acknowledged by the Right Hon. Lord Clydesmuir, P.C., G.C.I.E.

ELECTRICITY TARIFFS.

At a Press conference which was held at the Connaught Rooms, London, on Thursday, May 6, Lord Citrine announced that the British Electricity Authority have decided that charges for electricity must be adjusted in those districts where deficits have been forecast for 1948-49. He also said that the Area Boards were about to review flat-rate charges in excess of 6*d*. per kWh; and hoped that it would be possible to make some reduction in such rates in the near future. The argument for increases, which is, of course, what "adjustment" really means, is based on the fact that, taking the country as a whole, non-industrial consumers paid a lower average price last year than in 1938-39, although coal, wages and other costs had more than doubled during the period. Moreover, they have not suffered from the operation of the "coal clause," as have industrial consumers, with the result that they have been supplied at increasingly uneconomic prices. Since hostilities ceased, domestic consumption has risen sharply, while the sales of electricity for industrial purposes has only increased slightly. Finally, tariffs have been "stabilised" by the Government, with the result that reserves have been used up, losses are appearing, and 150 undertakings are operating under conditions which, if allowed to continue, would result in an aggregate deficit of nearly 7,000,000*l*. in 1948-49. Little criticism, as regards either fact or presentation, can be made of the policy inherent in this announcement. It is to be hoped, however, that no precipitate action will be taken. Unlike either the coal industry or the railways, the financial position of electricity supply is generally sound. It would, therefore, be a mistake to do anything that would cause unnecessary disturbance. That this is recognised is indicated by the statements of more than one Area chairman, which show that though the sword is suspended it may not fall everywhere just yet. The problem of electricity tariffs, however, is one which must be tackled seriously before long. In some areas, as is recognised, flat-rate prices are too high. In others, domestic consumers are being subsidised by power users and in equity some adjustment may be necessary. In others, again, prices in contiguous districts differ in a way which defies reasonable explanation. All this is, of course, due to the way the industry has grown up; and it is high time that the necessary alterations were made. This will be a difficult task and will demand the formulation of clear and simple principles of action. Fortunately, it will be rendered easier by the fact that the bulk-supply tariffs, under which the Central Authority will supply the Area Boards, conform to one standard, even if they are not exactly the same.

LONDON ASSOCIATION OF ENGINEERS.

The 96th anniversary of the foundation, in 1852, of the London Association of Engineers was marked on Friday, May 7, by a dinner held in the Connaught Rooms, London, W.C.2, under the chairmanship of Lord Dudley Gordon, D.S.O. The principal guest was the Rt. Hon. Hugh Gaitskell, M.P., Minister of Fuel and Power, who, in response to the toast of "His Majesty's Ministers," proposed by Lord Piercy, took credit for the claim that His Majesty's present Ministers had not shrunk from taking unpopular decisions if these were felt to be necessary. Possibly the most important part of Mr. Gaitskell's speech was his reference (apropos of earlier remarks by Lord Sempill, in proposing the toast of "The Engineering Industry," to which Vice-Admiral (E) D. C. Ford, Engineer-in-Chief of the Fleet, responded), to the "grave world oil shortage" resulting from the increasing world demand for petroleum products; especially in the United States, which now consumed two-thirds of the world output, or some 500 gallons annually per head, as compared with an annual consumption of 80 gallons per head in Great Britain. The toast of "The London Association of Engineers" was proposed by Lord Dudley Gordon, who referred to the fact that, originally, and for many years thereafter, it had been "The London Association of Foremen Engineers," and still contained in its membership a large proportion of foremen of engineering works. Foremen, he said, often found it advisable, on appointment to that grade and responsibility, to relinquish any trade-union membership that they might have held, and with it their union pension and insurance rights. It was a main function of the Association to maintain a Benevolent Fund which, in cases of necessity, would compensate for that deprivation, and he appealed to the members to support the Fund to the best of their ability. The toast having been acknowledged by the President of the Association (Mr. C. F. Kingham, A.I.Mech.E.), and that of "The Guests" having been proposed by Mr. W. J. Haycroft and acknowledged by Major-General A. W. Sproull, C.B.E., the Very Rev. Dr. W. R. Matthews, Dean of St. Paul's Cathedral, proposed the toast of the "Donors, Past and Present"—and, he added, "Future"—which provided Sir Ian Stewart Richardson, Bt., with an opportunity to express some views on the present difficulties of industry in general that the members present were not slow to endorse. The proceedings concluded with a toast to "The Chairman," proposed by Mr. C. F. Kingham, and duly acknowledged by Lord Dudley Gordon.

THE SOUTHERN ELECTRICITY BOARD.

Mr. H. Nimmo, chairman of the Southern Electricity Board, gave an informative account of the organisation of that body at a Press conference held at Maidenhead on Tuesday, May 4. He said that the Southern Board had taken over 22 local authority and 26 company supply undertakings under the Electricity Act, 1947. Its area extended from Chiswick to Portland Bill, and covered 6,500 square miles of territory with a population of over 3,000,000. The number of consumers was about 800,000 and the annual revenue 14,000,000*l*. For operational purposes, the area had been divided into four sub-areas with headquarters at Southall, Newbury, Portsmouth and Bournemouth, there being a manager, principal administrative officer, senior engineer, senior accountant, and senior commercial officer in each. Local or district executive officers, who had been given a considerable degree of autonomy, were responsible for day-to-day operation. When the Consultative Council for the area was set up, the consumer would have a more effective voice than before. Dealing with the question of prices, to which reference is made in another note on this page, Mr. Nimmo said that the position in the area as a whole was being examined and, where electricity was being sold at a loss, adjustments would be necessary. The selling price clearly must be related to the cost price and here the price of coal was a major factor. The first task would be to get a greater uniformity in methods of charging. The main reason for the restrictions on normal development, which had recently been imposed, was the shortage of generating plant, although difficulties in obtaining wooden poles would retard rural development. Even under these conditions, however, the increase in the demand for electricity was running at the rate of 10 per cent. annually. This meant that the generating plant position would only become easier when the capacity of the plant installed during the next few years exceeded 1,000 MW per annum.

INSTITUTION OF ELECTRICAL ENGINEERS.

The report of the Council for 1947-48, which was presented at the annual general meeting of the Institution of Electrical Engineers on Thursday, May 13, records that the work of the various technical committees has been steadily maintained, while in the educational field the session has been marked by the publication of a report on "Practical Training of Professional Electrical Engineers." During the session, arrangements have been proceeding for holding a conference in London next autumn of representatives of the engineering institutions in Western Europe and the United States. The total membership of the Institution is now 32,907, compared with 31,260 a year ago; of these, 15,206 are corporate members. During the 12 months ended March 31, 1948, 1,202 meetings were held in London and at the local centres by members, the council and the various committees. Activities during the year included the holding of a Convention on automatic regulators and servo-mechanisms by the Measurements Section and collaboration with the Institute of Physics and the Physical Society in the commemoration of the fiftieth anniversary of the discovery of the electron by J. J. Thomson. It is recorded that close co-operation continues to be maintained between the Institutions of Civil, Mechanical and Electrical Engineers, the presidents of which have met informally a number of times during the session to discuss methods of securing unity of purpose on subjects of common concern. As a result of representations made by the three Engineering Advisory Committees of the Ministry of Labour and National Service, the Technical Personnel Committee, of which Lord Hankey is chairman, have appointed panels dealing with the fields of civil, mechanical and electrical engineering to inquire into the present and prospective requirements for professionally qualified staff for the whole

engineering profession; and to recommend steps to be taken to meet any ascertained shortage. The findings of these panels will be issued as an official Government publication.

AN IRISH RAILWAY CENTENARY.

The unaccountable disappearance of a wagon from the centre of a goods train travelling on a single line would normally cast suspicion on the sanity of the train crew, and a Ministry of Transport inspecting officer would not rest content until he had found a rational explanation. In Ireland, however, it is sufficient to record that "the mystery was never solved, but some days later gangers found the wagon resting among bushes at the foot of an embankment at a place called Ballynashee, which means 'the place of the fairies.'" This incident is recalled in a booklet published to commemorate the centenary of the opening, on April 11, 1848, of the Belfast and Ballymena Railway. Extended, and enlarged by absorbing other companies, the railway was acquired by the Midland Railway in 1903, since when it has been managed by the Northern Counties Committee. As Viscount Massereene and Ferrard, the chairman of the committee, states in a foreword, much valuable historical material was lost during the air raid on Belfast in May, 1941, but a short summary of the principal events has been recorded in the booklet. The Irish broad gauge, 5 ft. 3 in., predominates on the system, there being 202 miles open, but there are also 43 miles of 3-ft. gauge single track. From Belfast to Whitehead and Ballymena there are double tracks, but the remainder of the system is laid with single track. At the time of the opening, a hundred years ago, the line had been laid as far as Carrickfergus, Randalstown and Ballymena. In 1855, in conjunction with other railways, the line to Londonderry was completed, although, in the absence of a viaduct over the River Bann, passengers were obliged to change stations at Coleraine. Notable features of the railway have been the services connecting with steamships at Belfast and Larne, and the omnibus and lorry services which, however, were absorbed by the Northern Ireland Road Transport Board in 1935.

THE ENGINEERS' GUILD.

The annual general meeting of the Engineers' Guild was held in Caxton Hall, Westminster, S.W.1, on Wednesday, May 12, the chair being taken by Mr. Robert Chalmers, O.B.E., who presented the Council's report and the annual accounts. The report showed that, during the year to March 31, 1948, the membership had shown a marked increase, especially after the meeting held in the same hall on March 10 (a report of which appeared on page 279, *ante*); it had increased, in fact, nearly four-fold, and, Mr. Chalmers added, subsequent accessions had brought the total up to more than 1,000, even though it had not been possible to circularise more than about a quarter of the 35,000 or so of the potential eligible membership of the Institutions of Civil, Mechanical and Electrical Engineers. Arrangements had been made with a firm of chartered accountants, Messrs. Arnold Hill and Company, of 28, Victoria-street, S.W.1, to provide secretarial assistance and an address to which Guild correspondence could be directed; and discussions were proceeding on the preliminaries necessary to incorporation—preferably, in the Council's opinion, as a company limited by guarantee and having no share capital. Subsequent discussion by members at the meeting strongly endorsed the Council's preference in this matter.

AUTOMATIC CONTROL OF STREET LIGHTING.—"Rhythmatic" control for street lighting has recently been installed at Lytham St. Annes, Lancashire, by the Automatic Telephone and Electric Company, Limited, Liverpool, 7, and was inaugurated by the Mayor (Councillor J. R. Butterfield, J.P.) on Thursday, April 29. The system, the principles of which were described on page 318 of our 164th volume (1947), deals with a public-lighting load of just over 300 kW. This is divided into five groups, which are controlled by injecting current at 1,500 cycles per second into the mains. Appropriate relays are thus operated and switching "off" and "on" can be effected from a central point. Pre-selected loads of low priority can also be switched off by the same means at peak-load periods.

THE STORY OF ATOMIC ENERGY.*

XIII.—THE FUTURE OF ATOMIC ENERGY.

By DR. FREDERICK SODDY, F.R.S.

CONCLUSION.

THIS brings to an end the story of atomic energy, so far as yet publicly revealed and in so far as concerns the positive advances in fundamental science it chronicles. The object has been to trace the origins of the numerous new ideas and discoveries, in the hope that these at least can be made generally intelligible, rather than to attempt any presentation of how this complex subject presents itself to-day, which indeed, without an appreciation of its origins, might prove very misleading. For we are in such a new physical world that analogy, except on the most general lines, is a dangerous guide. Nevertheless, it does appear necessary to the writer that he should give his own critical opinion as to how far the general problem of transmutation, and with it the release of atomic energy by human contrivance, has actually yet succeeded, and of the long road that may still lie ahead before any worth while application of it to the more mundane affairs of life becomes practicable.

THE SOCIAL RESPONSIBILITY OF THE SCIENTIST.

Also, the question uppermost in the public mind with regard to this new development, as raising the issue of the responsibility of science and the scientific worker to the whole community and to the world, must be mentioned, and the writer's own opinions stated. Though in this respect, it is not his fault if they remain unknown, as, ever since the First World War, for the past 25 years, he has been practically alone in giving earnest attention to the cause of the inversion of science, and, so far as an unsupported individual in these days is able to do so, making his conclusions known to the public. These and the remedy proposed remain the same as when first arrived at. Broadly, the evil, or devil, has been the wilful falsification of the distribution system by bad money, not the enlarged potentialities of production made possible by science. That is what we have to thank for the now famous and familiar description of the scientific age as poverty in the midst of plenty. But there has never been the slightest intellectual interest shown by the public as to whether this is or is not true. All they seem to think important is what the majority think, who nowadays hardly exercise any appreciable effect at all over the course of future events, less so now than they ever did.

In this concluding section, he is, of course, speaking entirely as an individual scientist, completely outside of any official connection whatever, and in the war-aspect of the work described only in possession of what has been publicly divulged so far. The conditions of secrecy still imposed on those actually responsible for the progress of the work for war-purposes, preclude any consensus of scientific judgment having yet been arrived at, or, if it had, from being worth much. For atomic energy already seems to have been treated as just another political carrot to keep the common peoples of the world hopefully jogging along.

In the writer's view, then, it is far from a justified or justifiable inference from what is known to have been achieved already, that even the purely scientific problem has been solved sufficiently yet to enter at all fundamentally into the constructive affairs of our everyday life. Destruction is always easier than construction, and never more so than in the new field that has been opened up. It is universally agreed that, unless positively prevented, the new destructive weapon may destroy anything that can be called civilisation, and again reduce human life on this planet, if it survives at all, to a primitive type of economy, maintained by scattered groups or individual families living directly by cultivation of the soil. But it is not yet certain that the present knowledge does allow the existing type of civilisation, that science has substituted for the primitive, to be carried on any easier or better, let alone to progress faster in its present direction. For it has not yet advanced beyond the purely scientific stage far enough to warrant any forecast of its technological possibilities, and, indeed, may never advance, even as pure science, to the point where they become possibilities.

THE NATURAL SOURCES OF URANIUM.

The flood of speculation that has followed the spectacular demonstration of its destructive power rather seems to assume that the general problem had been solved, whereas it has been solved only for one special case, the 235 isotope of uranium, present in less than one per cent. of the natural mixture of isotopes, which is itself an element, still only known to exist in workable concentration in very few localities, in spite of 40 or 50 years search for it to supply radium. The first great unknown, indeed, is how far the new demand will result in increased supply. Practically all the radium so far produced has come from four sources, first from the old State silver mine of St. Joachimsthal, Bohemia; then from the Paradox Valley, Colorado, and other United States deposits of a very low grade, but easily worked, carnotite; then from a very rich find of many hundreds of tons of pitchblende at Katanga, Belgian Congo; and now from another and larger concentration in the Great Bear Lake area, on the Arctic Circle, in Canada. Even in its geographical distribution uranium seems exceptional, in that no other heavy element, except lead, occurs like it in a few enormous local ore-concentrations. It is true that the same applies, to some extent, to thorium also, but here it is brought about by the action of the waves and winds, concentrating the infinitesimal quantities of the heavier monazite sand that occurs in many rocks, along certain shores of the sea, or what once were littoral areas.

WHY WASTE URANIUM?

It certainly has put into the armoury of the scientific researcher a new and powerful means of investigation, and, in the writer's view, it would be much better to confine its use for the next few years to such purposes, rather than to waste a unique, and possibly irreplaceable, material in doing things much better done by existing means, or otherwise degrading it to tasks quite unworthy of its unique powers. As for the facile suggestions to use it for aeroplanes or even ships, the lethal character of the radiations emitted in these sub-atomic changes seem to make all such silly. It has just been revealed, May, 1947, that the ships used as targets for the Bikini tests, ten months previously, are still uninhabitable by reason of their radioactivity. The only real protection against these rays is the square of the distance law, as obeyed by all radiation—the not-being-there, in fact, as the United States scientists have put it—and the only type of plant operable seems to be that at Hanford, as far as possible removed from populous centres, and wholly or in part below ground.

INTENSITY AND QUANTITY IN ENERGETICS.

In this connection clearer thinking seems to be called for. It is not possible, and there is no reason yet to suppose that it ever will be possible, to moderate the intensity of the individual atomic disintegration or fission. Control, here, simply means regulating the number of atoms that break up in the time-unit. The individual fission is in the region between the 100 and 200 M.e.v. level, giving rays far more energetic than those of radium, which are in the 1 to 10 M.e.v. range, and they are probably even more deadly, in their direct and delayed actions, to living organisations than any of which we had previous experience.

The fact is that a new great step-up in energy-level like this makes possible new technological achievements, and that any general attempt to degrade them to the level of serving old ones is a step in the wrong direction. A close enough

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* This completes the series of articles in which Dr. Soddy's new book has been published in "ENGINEERING." Dr. Soddy hopes to be able to publish the work as a bound volume, after a larger book now in preparation on the same subject, has appeared. As soon as the arrangements have been completed an announcement will be made in our columns.—ED. E.

analogy exists even in the case of ordinary explosives. In the modern high-explosives, as the fulminates, dynamite, T.N.T., and the like, the detonating quality is self-contained in the individual molecule, not in a mixture of them that can be diluted to the desired extent, as in gunpowder and the explosive mixture of the gas-engine. One does not use high-explosives for producing power but for destructive purposes.

So, *a fortiori*, the destructive purpose for which the tomic bomb has already been employed is its obvious natural application. Tomic energy might be usefully employed in tasks of civil and mining engineering otherwise beyond our powers, as, for example, to blast shorter communications between the oceans, to bring some of the civilising and ameliorating influences of the sea into the vast land-locked regions of the globe, or in exposing and rendering accessible hidden mineral resources underground, and such like tasks. For this reason, the proposals recently put forth by the Atomic Energy Commission to "denature" fissionable material before release, whatever that may mean, in order to make its restoration too irksome to restore its explosive quality, and so as to confine its use to "peaceful" applications, seem to amount to making it not worth while to use it for any technological purpose at all.

True, from such installations as those at Hanford there is a very great amount of energy going to waste for which it might be possible to find better uses than warming the Columbia River. But this is true, if in less flagrant degree, of all large fuel-operated power-plants, which, for a similar reason, are generally sited on large rivers, and part of their power allowed to go to waste. In either case a better use could be made of such waste heat, as in intensive horticulture to warm plant forcing houses, if the era ending had been less scandalously profligate of its rapidly dwindling fuel supplies. Naturally, if the world's fuel resources gave out before the new possibilities make them obsolete, what is already known would be capable of being developed more or less well as a partial substitute.

No doubt, in due course, so far as the purely technical difficulties are involved, the engineers may be trusted to adapt the uranium pile to operate at higher temperatures for the provision of high-grade power, rather than waste-heat. But it must be remembered that the radiations have destructive effects not only on life, but on many of the common engineering materials, and the proposition rather sounds at present like using a steam-hammer to crack a nut, even if it does not prove a chimera.

The Undisclosed Datum.

For there are grounds for the belief that there still is a very long way to go before anything much of practical economic significance will come of the present state of the subject. Difficult to a degree, and even heroic, as these first successes have been, the further one recedes from them in time the more they take on the light of an acrobatic feat, a giant's turn of strength, rather than an all-round-the-clock engineering accomplishment. Usually, in any great technological advance it is the first step that counts, but here it seems rather to be a case of skimming the milk for the cream. The phenomenon of pile "poisoning" in conjunction with the mysterious reference, just alluded to, concerning "denaturing" fissionable material, also indicates this. But the main reason is that, in the uranium pile, the active 235 isotope is being steadily consumed without replacement. The margin by which the pile works—and that is the same as the proportion of this 0·7 per cent. utilisable—is exceedingly narrow, even for fresh uranium and when no extraneous neutron-absorber, such as the simple water-cooling system so far employed, is incorporated. If this latter were complex enough to enable higher temperatures to be used safely, it would bring the system still nearer the point at which the absorption of neutrons would stop the pile operating, even with unused fresh natural uranium. Hence, less and less of the already only very small fraction of the 0·7 per cent. proportion 235 isotope becomes available for the liberation of tomic energy, both for these reasons and because of its steady consumption in the process.

Here we come to the question, unanswerable on the data so far released, as to how far, for purely "peace" uses, the plutonium actually produced and separated from the "poisoning" fission-products, if put back into the pile will compensate the using up of the 235 isotope primarily concerned in producing it. If more than one atom of plutonium is recovered for every atom of U 235 used up, then the original hope, that the method may enable the energy of the 238 isotope, which is in vast preponderance, also to be liberated, becomes theoretically possible, but not otherwise. This seems to be the lacuna in public knowledge, already mentioned, upon which the practical value of the process so far operated really turns. But such indications as exist seem to make the availability of the U 238 highly problematical. If it be available, then the alternative use of the recovered plutonium for tomic bombs, instead of for revivifying the pile, still remains unguarded against. The fact is that the United States official publication, *Atomic Energy*, which, in its concluding section, states that its object is to enable scientific men to help their fellow-citizens to reach wise political conclusions as to the future use of atomic energy, and on which the writer relies mainly for the final chapter of the story, is too vague on the point mentioned, and on "poisoning" in general, for such a purpose. The later released hints, as to "denaturing" uranium, have thrown the whole subject into further confusion. As already pointed out, any such process, if really effective, would seem also to render the material useless for any worth-while purpose at all.

Mutation and the New Radiations.

Lastly, one other possible consequence to life of the new types of radiation now at our command, may at least be mentioned, though, being outside the writer's field, it is not a congenial topic. It is the possibility that they may prove to be the missing key, or one of them, to evolution. Some time ago, it had been suggested by Hamshaw Thomas, rather fancifully, as it seemed at the time, that the mutation of plant life and the origin of new species might be caused by cosmical radiation. The evidence was mainly in the botanical distribution of varieties, in that a much greater number occur on high plateaux than at sea-level. Thus, there are 330 species of mountain primulas against 19 for the plains. In Costa Rica, a narrow isthmus one-half of it above the 3,000 ft. level, there are as many vascular plants as in the whole south-east of the United States. The crop plants of the world's agriculture are all derived from seven or eight centres, all mountainous and within 40 deg. of the Equator. This, however, it might be thought, could as well be an effect of ultra-violet light as of cosmical radiation. But it is now claimed that X-rays, and, more recently, neutrons, are able to induce mutations in dividing cells, and one of the 1946 Nobel Prizes was awarded to an American, Dr. H. J. Muller, for similar work.

We are indebted to the American journalist, John Hersey, for disclosing that the bombing of Hiroshima was followed shortly afterwards by an amazing efflorescence of vegetation there, quickly effacing the original scorched devastation produced by the flash and blast. The large collection of living animals exposed to the effects of the bombs subsequently detonated in the Bikini naval tests, also suggests that physiological consequences in the victims of Hiroshima and Nagasaki may, in part, have been the subject of investigation. So far, though two of the leading scientists engaged in the final work on the assembly of the tomic bomb are reported to have lost their lives through accidental full exposure to the radiation, there is nothing known as yet suggesting any after-effects on the personnel operating the processes. For these, from the start, the most elaborate precautions were taken to prevent exposure and in the measures taken to detect incipient symptoms and generally to maintain health. It is too early yet to form any opinion on whether these matters may prove to have any unusual importance or connection with the new energy-levels reached. But in any attempt to foresee the future possibilities opening up, sufficient seems to have been learned already to warrant mentioning the biological aspect.

The Proper Use of the New Knowledge.

The best hope for the future of atomic energy seems to lie rather on the wise use of the purely scientific knowledge accumulated, in order to widen the field and to gain more, rather than in wasting valuable material and effort in premature technological projects of very problematical advantage. The uranium pile is still the only source of neutrons in quantity, the lack of which previously was the greatest barrier to progress. At the same time, the new theory of the nucleus, as analogous to a liquid drop rather than to an architectural structure like a molecule, makes it reasonable to expect, as Seaborg does, that by pushing the original methods to higher energy-levels, new and unexpected avenues of approach to the problem may open out, less restricted in their applicability than those so far revealed.

Quite apart from the over-riding necessity, if the world is to be saved from destruction, of making the use of the atomic bomb impossible as a war-weapon, some truly international scientific control over research in the whole subject seems now to be called for, if only because the effort and expenditure required become ever-increasingly colossal, and only so can it be economically justified. But an even more important reason is that the particular techniques required are too difficult for those who wish to apply them to initiate and learn from the beginning themselves, and such, once perfected to the limit of the existing knowledge, ought to be put under expert professional continuous operation and made available to the properly qualified scientific world of all nations for their special inquiries.

A Working Example of International Science.

So far in this field we have had a plethora of the sort of government of those who know by those who do not, by which the world has been and now, more than ever, is being endangered. So that it may be as well to give the public an illustration of what, in the writer's meaning, international control and co-operation involve. For, since the beginning of this century, there has been one good working example of such for a single scientific objective, due to the wise employment of a benefaction, one of the objects of which was to train laboratory assistants to a more professional level in order to facilitate such work. It is the world-famous Cryogenic Laboratory of Leiden University, Holland, to which investigators from all over the world wishing to study phenomena at low temperatures have repaired, each, of course, a master in his own particular technique but finding there the particular technique of low temperature provision supplied him by trained operators of it. Much in the same way, the giant cyclotron at Berkeley University, California, when it is perfected, and its products, ought to be made internationally available for duly qualified investigators, rather than each country trying to do over again what the pioneers have already done.

Science and the Community.

This inevitably raises the larger question of the relation of the scientific worker to the community, and his responsibility for the use rather than abuse of his work, hitherto not discussed as being outside the scope of this work; also, being beyond any purely scientific solution, it is therefore very uncongenial. But it is impossible for any scientific man any longer to ignore the issue, on grounds that before seemed adequate, as being one in which, by the wisdom of his superiors, he has hitherto been about the only professional class in the community not deemed to be a party to the use the community may choose to make of his brains, and, indeed, expected, as a matter of course, to do as he is ordered, like a mere private in the ranks of the economic or military forces, as the case may be. The community, perforce, has always had to acquiesce in the powers of life and death a professional doctor exercises over his individual patients, and which now the research scientist exercises over the whole community. The doctor is protected by the medical code and the Hippocratic oath which he is required to take before being allowed to practise his profession, from outside economic and military orders to abuse his knowledge. Until the last War, certainly, this necessity

does not seem to have cost the well-to-do community, at least, any loss of sleep. The denigration of the "scientist," openly malicious in the writer's youth, but now more usually oblique and veiled, comes in fact from the people who used, in former regimes, to wield such powers, but who now have been supplanted by the march of events. Instead of abdicating that function they are trying to preserve it by controlling science, about which their education still leaves them, more frequently than not, in total ignorance.

It is perhaps significant that Sir Henry Dale, till lately President of the Royal Society, is a professional medical man, and that his contribution to this issue, in a recent address in Washington, was original. It was that the universities of the world should bind themselves together to bring about international agreement not to carry on any scientific work under military secrecy. Whereas his successor, Sir Robert Robinson, an organic chemist whose work lies on its borderland with bio-chemistry, in his first Anniversary Address to the Royal Society, apparently applauds only the still remaining freedom of the individual universities in this country to refuse, in their extra-mural contracts, those containing clauses restricting free publication of results. Probably no one else would think such a point of much importance. He points out that there is no clear-cut distinction between war and peace, and that it is illogical to condemn scientists for doing in the latter what they are so highly applauded for doing in the former. He favours the outlawry by scientists of all forms of "total war"—aerial bombardment of cities, chemical warfare, biological warfare, use of atom bombs, and any similar "future devilries" devised. But it is fresh in everyone's memory that they made not the slightest attempt to do so during the War just ended, and no one seriously expects them, or for that matter, anyone else, to be any more resistant in the next.

The Total Abolition of War.

The United States scientists, on the other hand, primarily responsible for the achievement that led to the tomic bomb, seem to have been singularly unanimous in condemning not "total war," refusal to engage in which offers the alternative nowadays of total annihilation, but in total abolition of war as the only logical course, if civilisation is to survive. In this, undoubtedly, they are at one with the common instincts of self-preservation of all humanity. The attempt to shy away from the real issue under cover of a new meaningless phrase for what is as old as mankind, will certainly comfort nobody. It is merely the last-ditch attempt of the blind to lead the blind.

In the writer's view, until international authority, as Sir Henry Dale has suggested, if in a less drastic proposal, exists strong enough to compel scientists, like medical men, to obey a code of ethics drawn up for their protection and guidance, and requires from them an oath that they will not be a party to assisting in war work before allowing them to engage in scientific work, having adequate power to withhold the means of their doing so, at all events in the case of the more modern costly and dangerous devices and material, there is practically no hope of peace in the world, save of the Roman type, enforceable by sheer military domination of one single Power over all the rest.

The Divorce of Science from Culture, Philosophy and Government.

This purely scientific international authority governing scientific men and their work seems the first step to aim at. In the ancient civilisation of Egypt, science was the secret of the ruling heirarchy and permitted to be practised only by those of royal blood. In the Greek, it was considered, at first at least, before Plato and Aristotle sent it off the rails for a couple of thousand years, as much an essential part of culture and philosophical inquiry as those appertaining to man in particular, and the four centuries of subsequent revelation of natural law in the material universe has so far done little or nothing to re-unite science and philosophy. Indeed, one cannot but contrast the robust common-sense of the pre-Christian era, in its religious outlook towards the world of Nature and the inculcation of a healthy respect for its dread powers, with the spineless and one-eyed attitude towards the problem now facing all humanity among the surviving religious monists of to-day. Their own motto about putting first things first actually puts first things last, and it is a chastening thought to the physical scientist, straying from the relative certainty of his own material world, how much of what passes for profundity and wisdom seems little more than a dogged determination of the baffled human mind to invert the world of fact and commonsense, to affirm that black is white, and escape into the unreal world of its own creation.

The six disastrous years of World War in which, with the mastery of the air, weapons of destruction, even without the tomic bomb, gained final and definite ascendancy over any possible rate of recuperation or reconstruction, now seems only to have unloosed among the masses a false optimism that the same efforts guided into constructive channels could emancipate the whole world, whereas, in fact, it represented so great a disaster as to postpone indefinitely any such possibility, if not now to make it too late, even were peace perpetually secured. The world now is already confronted rather with the beginning of failing resources both in fuel and in food. Last century, not this, was the proper time to attempt the millenium, but that chance was deliberately wrecked, from the first puff of the steam-engine, by choking the channels of distribution by a false monetary system and similar tricks of government at the card-sharping level from which modern wars and revolutions are the natural result. Indeed, this seems to be much what all government as now understood amounts to in consequence.

However easy it is to trick men, it is not possible to trick Nature, as every scientist knows. So what is equally necessary to protecting scientists from prostituting their gifts and talents, by assisting in the devising and improvement of methods of destruction for war purposes, is that the moralists and the religious world should relearn the meaning of truth as understood by the Greeks as by scientific men, applying not merely to mystical and transcendental matters but also to physical arithmetic. For the penalties for offending the god of world wealth accountancy are nowadays capable of producing a far more universal cataclysm than all the pecadillos men have been taught to regard as the seven deadly sins. If ethics and religion are to assist in, rather than resist and try to sabotage improvement in the world, at all commensurate in their sphere with that now possible in the economic and physical sphere, they have much to learn from science, in respecting and aligning themselves with natural law, rather than in treating it as the enemy. They might also seriously reconsider whether their own preoccupations are so immeasurably superior to the more mundane and more basic principles of energy and matter by which all men live, move and have their being. As the German chemist aptly put it—without phosphorus no thought.

Diesel-Electric Locomotives for British Railways.—Three Diesel-electric locomotives to a new design are now under construction at Brighton locomotive works, and are expected to be completed at the end of the year, when trials will be run on West of England main-line traffic.

The Universities and the Steel Industry.—The United Steel Companies, Limited, recently invited 14 professors of mechanical engineering from 11 different universities to visit their works in Sheffield and Scunthorpe. During the visit which lasted four days, discussions were arranged on the dependence of metallurgical developments on engineering research, with particular reference to such problems as the handling of scrap and the flow of gases in open-hearth furnaces. Another discussion on industrial research was opened by Sir Charles Goodeve, F.R.S., Director of the British Iron and Steel Research Association. The visitors comprised Professors G. F. Mucklow, D.Sc., and T. U. Matthew, D.Sc. (Birmingham); A. Robertson, D.Sc., F.R.S., and J. L. M. Morrison, D.Sc. (Bristol); A. F. Burstall, D.Sc., (Durham); R. M. Arnold, D.Sc. (Edinburgh); G. Cook, D.Sc., F.R.S., and A. S. T. Thomson, D.Sc. (Glasgow); N. J. Kearton, D.Sc. (Liverpool); E. Giffin, Ph.D. (London); H. Wright Baker, D.Sc. (Manchester); C. H. Bulleid, O.B.E. (Nottingham); H. W. Swift, D.Sc., (Sheffield); and T. R. Cave-Browne-Cave, C.B.E. (Southampton).

THE IRON AND STEEL INSTITUTE.

(*Continued from page* 450.)

Continuing our report of the annual general meeting of the Iron and Steel Institute, held in London on May 5 and 6, we deal below with the proceedings which followed the delivery of the presidential address on the first morning, Wednesday, May 5.

Open-Hearth Furnaces.

The remainder of the session was devoted to the joint discussion of three papers dealing with open-hearth furnaces after they had been presented, in turn, by their authors. The papers comprised "Construction and Repair of Open-Hearth Furnaces," by Mr. D. C. Muir; "The Design of Open-Hearth Gas Ports," by Mr. M. P. Newby; and "Installation and Use of Instruments on Open-Hearth Melting Furnaces," by Mr. R. C. Baker. Mr. Muir, in his paper, described the furnace-repair programme at the works of the Consett Iron Company, Limited. He said that the melting shop contained seven basic and three acid furnaces, all of the fixed type. The basic furnaces and two of the acid furnaces were of 75 tons capacity and the remaining acid furnace was of 40 tons nominal capacity. A system of balanced repairs had been adopted and this enabled nine out of the ten furnaces to be in production at any one time. Two parts of a furnace which necessitated closing down for repair work were the roof and the chequers. By means of the system of balanced repairs the shut down was arranged so that the maximum amount of repairs could be done in the time available. The length of the acid-furnace campaigns was fixed at 24 weeks, while the target for the basic furnaces was set at 30 weeks, with a close down about halfway for a top dressing. At the present time it was found that after 15 weeks the blocks, back lining, air uptakes, and roof were in a condition to benefit from a complete renewal, and at the same time the upper ten courses of chequers were taken out and replaced. The arrangements for the removal of scrap material from a demolished furnace and for the supply of building materials in their correct sequence on the site could influence greatly the speed at which the furnace was rebuilt. Such arrangements required the closest co-operation between the melting-shop management, the foreman bricklayer and the traffic department. Since the paper had been written, one of the 75-ton basic furnaces had been pulled down and a 150-ton basic furnace, with enlarged slag pockets, regenerators and flues, had been constructed on new foundations. This had been done in less than nine weeks. Mr. Muir added that various difficulties would be encountered with all-basic construction; but it was certain that they would be overcome in time. It was still more certain that the full benefits of high-quality fuels would not be realised until the limitation imposed by the silica roof was removed from the basic furnace.

In the second paper, on "The Design of Open-Hearth Gas Ports," Mr. M. P. Newby described experiments carried out by the British Iron and Steel Research Association on a model of the gas port of a producer-gas fired open-hearth furnace. The K furnace at the Templeborough Works of Messrs. Steel, Peech and Tozer, Limited, had been chosen as a basis for the experiments. One-twelfth scale models of the gas uptake and the port had been constructed. The models were built on to a rectangular box which approximated in shape and size to the furnace chamber but was made without the charging doors. The experiments had been carried out by blowing air through the model at such velocities that the same range of Reynolds numbers could be covered in the model port throat as occurred in the full-scale furnace. The port had been built up from wooden blocks, Perspex sheet, and modelling clay, to facilitate rapid variations of design. The object of the experiments had been to determine the efficiency of a port considered as an arrangement for converting pressure energy into kinetic energy of gas motion. The resistance of the port to the outgoing products

of combustion had also been measured. The results had shown that the designs tested had fairly high efficiency and that changes in design could bring only a limited improvement. Funnels added to the port, between the throat and the furnace chamber, gave considerable reduction of outgoing resistance but involved practical difficulties which made them of limited industrial value. The only way to increase the gas velocity substantially was to increase the pressure behind the port.

In the third paper on instruments in open-hearth melting furnaces, the author, Mr. R. C. Baker, of Messrs. John Baker and Bessemer, Limited, described the installation and development of instruments for routine use in a small plant consisting of one acid Venturi furnace of 50 tons capacity and a basic furnace of 40 tons capacity, making steels used mainly for the manufacture of railway tyres and wheels. Features of the system adopted were the recording of the furnace-roof temperature and of the flow of producer gas and air on one chart. An instrument for controlling automatically the temperature of the furnace crown was being experimented with. Experience indicated that the furnacemen appreciated the value of the instruments and relied on them far more than on observation of the flame and the furnace. Having confidence in them, the furnacemen were now using their instruments to endeavour to maintain the furnace crown at a predetermined limiting temperature for as long a period as possible. A maximum flow of gas was maintained for a considerably longer period, during charging and melting, than had been the case previously. Finally, owing to the adoption of these instruments and the use of immersion pyrometers, the bath temperature was under much better control than formerly. The cumulative effect was that there had been an increase in the melting rate, but as the instruments had been installed gradually over a period of years it was difficult to provide data.

The discussion was opened by Dr. J. H. Chesters, who stated that we had, in this country, an All-Basic Furnace Sub-Committee which had been working very actively for about a year. The main trouble, at present, was that there were no proper records of the furnaces which had already run their life. One more questionnaire was being formulated, and those who had built all-basic furnaces would be requested to supply information. The fact remained, however, that most firms would have to go on using silica roofs for a long time and it was very important to make a careful study of the factors which determined silica-roof life. The next speaker, Mr. F. L. Robertson, said that the introduction of instruments in the melting shop had brought two new problems. The first was that the melter found that there were too many instruments for him to attend to and the second was that the co-ordination of all these measurements, during the process of steelmaking, introduced further difficulties. Mr. Baker, however, had dealt with these problems, first by introducing automatic gear and afterwards by adopting multiple chart readings. Dr. A. H. Leckie, who spoke next, said that Mr. Baker had shown that it was just as important to install instruments in older and smaller shops, making special steels, as it was to adopt them in large new melting shops. He hoped that the paper would encourage steelmakers in Sheffield, South Wales and elsewhere, and show them that the installation of instruments did not mean the expenditure of thousands of pounds on glass-encased panels. Mr. Newby's work had been undertaken on account of the lack of data on friction factors in bends similar to those found in open-hearth furnaces.

Mr. M. W. Thring stated that the air model, used by Mr. Newby, was ideal for measuring mixing indices, actual factors of mixing, and pressure drops, but it was not nearly so good as a water model used by Dr. Chesters for showing flow patterns. Every time a furnace designer put forward a new shape of port, however, he should build an air model of it for testing purposes. Mr. Newby's work showed that much more could be done with an air port than with a gas port.

Mr. D. C. Muir, in the course of his reply, emphasised Dr. Chester's remarks concerning the work of the All-Basic Furnace Sub-Committee. With regard to the life of a silica roof, he would say that the roof should be patched as long as this could be done without wasting any time. Normally it would be done on a Saturday afternoon, but with the present continuous working week, it would mean taking a furnace off. Mr. M. P. Newby and Mr. R. C. Baker also briefly replied, the latter stating, in answer to Mr. Robertson's question regarding difficulties brought into the melting shop by instrumentation, that the solution of this was automatic control. Moreover, only the minimum number of instruments necessary for control purposes should be put on the main furnace panel. A secondary panel was used for any instruments which concerned the melting-shop manager or the fuel engineer.

At this stage of the proceedings the President adjourned the meeting until 2.30 that afternoon.

Structure of Cast Irons.

THE first two papers taken at the afternoon session, on May 5, dealt with the structure of cast irons and were discussed together. The first paper was entitled "The Production of Nodular Graphite in Cast Irons," and was by Mr. H. Morrogh and Mr. W. J. Williams, of the British Cast Iron Research Association. It was presented by Mr. Williams. The authors stated that they had made a study of the production of nodular structures in nickel-iron-carbon alloys and it had been found that additions of cerium to the molten alloys gave, on solidification, nodular structures in hyper-eutectic alloys even when these possessed very low nickel contents. When the alloys contained appreciable amounts of sulphur, however, no nodular structures were obtained. Attempts to produce nodular structures, by adding cerium to low-sulphur hypo-eutectic cast irons, had been only partly successful, but when hyper-eutectic irons were treated, structures consisting of hyper-eutectic spherulites and quasi-flake graphite were obtained. With increasing amounts of cerium in such irons the mechanical properties showed a progressive improvement. Cerium was a desulphuriser and a powerful carbide stabiliser, and one of its functions in producing nodular graphite structures was to reduce the sulphur content of the iron to a relatively low value. A study of the mechanism of the solidification of the irons had shown that the hyper-eutectic graphite formed in the liquid, with a spherulitic structure. The quasi flake graphite formed by the decomposition of a white-iron eutectic after solidification. In the vicinity of the hyper-eutectic spherulites the eutectic graphite was deposited upon the already existing nodules. When the number of hyper-eutectic nodules was increased artificially, no quasi flake graphite formed.

A process for accomplishing this had been developed and it involved the addition of a graphitising inoculant after the cerium addition. This treatment gave irons having the whole of the graphite in nodular form and the mechanical properties of such irons were very good. The cerium could be added to the cast iron in the form of *mischmetall* and the treatment must be applied to the metal shortly before casting. Cerium was lost on re-melting and a reversion to normal flake-graphite structure occurred. Grey cast irons containing nodular structures in the as-cast state were referred to as "nodular cast irons" and previously the only method available for producing such structures was by the lengthy annealing of white cast iron. Cast irons having nodular structures in the as-cast state, however, had mechanical properties differing from those of malleable cast iron. A new field in the metallurgy of cast irons had been opened, but it was too early to assess the commercial possibilities of the process, although successful trials on an industrial scale had been carried out. Further papers dealing with the practical issues involved in the application of this process would be presented in due course.

The second paper on the structure of cast iron was by Mr. D. Marles, of the British Cast Iron Research Association, and dealt with "The Carbides in Iron-Carbon-Silicon Alloys and Cast Irons." In presenting his paper, the author stated that he had made a metallographic study of the carbides occurring in cast irons and in iron-carbon-silicon alloys having silicon contents up to 7 per cent. and carbon content of 1·7 to 3·6 per cent. It had been found that with silicon contents in excess of about 2·5 per cent., a carbide phase appeared which did not respond to heat-tinting in the same way as normal cementite. With increase in silicon up to 7 per cent., this phase increased in amount, while the normal cementite decreased until, at 7 per cent., the carbide phase consisted entirely of the constituent not responsive to heat-tinting. Mr. Marles added, in conclusion, that he favoured the view, put forward in 1910 by Stead, that some combination of silicon and iron carbide occurred and that the iron carbide not responsive to heat tinting was an iron silico-carbide having a lower stability at elevated temperatures than normal cementite.

Dr. L. B. Pfeil, who opened the discussion, said that the paper by Morrogh and Williams represented an important advance towards a goal for which many had striven in recent years, namely, the commercial production of cast irons in which the as-cast condition would have a nodular graphite structure. It seemed that engineers could quite reasonably anticipate having, in the near future, what really amounted to a new low-cost alloy at their disposal. This material really deserved the term "new alloy," and should play an important part in engineering construction in the future. Mr. W. S. Owen, who spoke next on the paper by Mr. Marles, said that any discussion of the carbide phases in cast iron was bound to be inconclusive as our present knowledge of the stable and metastable iron-carbon-silicon systems was based on inadequate experimental data, particularly in the higher silicon regions. The next speaker, Mr. M. M. Hallett, said that his experience had confirmed the claims of Morrogh and Williams. Nodular cast iron could be produced in the foundry having a tensile strength of at least 35 tons per square inch, in 2·1-in. diameter test bars, and with an almost entirely pearlitic matrix. Much work, however, would have to be done in determining the exact mechanism of nodular graphite and the temperature at which it formed.

Mr. K. H. Wright said that while the results of the researches by Morrogh and Williams had given industry a new material with which to work, they were capable of a much broader interpretation, and ultimately would lead to a more complete understanding of the apparent anomalies which were encountered in normal-flake graphite irons. A possible link which might elucidate hitherto inexplicable points was sulphur; the control of sulphur appeared to be of great importance when producing nodular iron. A subsequent speaker, Mr. R. J. Brown, said that, in their conclusions, Messrs. Morrogh and Williams had pointed out that the problem was to determine the mode of formation, as spherules, of the hypo-eutectic graphite. Examination of a number of castings provided absolute evidence that, for a given composition, mass effect played a large part in the formation of nodular graphite. With castings of varying sections it was quite usual to obtain a white crystalline fracture in the thin sections and a partially mottled fracture in the heavier sections, although judicious adjustment of the composition of the metal might be successful in producing a white crystalline fracture throughout. A consideration of the structures at different locations in a single casting of uniform composition, indicated that cooling rate could not be dissociated from the formation of spherulitic graphite in cerium-treated cast iron. The last speaker, Dr. J. H. Whiteley, asked Mr. Marles if he had tried the effect of cold sodium picrate on his silico-carbide.

Mr. Williams, in reply, said that Mr. Morrogh and he had gone into the subject of the mechanism of the formation of quasi-flake and nodular graphite and had a good deal of information on it. The present paper, however, attempted to give details of the production of the new iron and not of the mechanism of its formation nor of the action of cerium. The mechanism of solidification of these irons was very involved and would probably be the subject of another paper. In a brief reply to the discussion on his paper, Mr. Marles said that he had tried boiling alkaline picrate but had not obtained differentiation between the two carbides. Cold sodium picrate had not been tried as it had not been thought to be a useful reagent.

(To be continued.)

CONTRACTS.

MESSRS. ASSOCIATED BRITISH OIL ENGINES, LIMITED, Duke's Court, 32, Duke-street, St. James's, London, S.W.1, are supplying 26 sets of Diesel-electric auxiliaries to several shipbuilding firms for installation in ships which they are constructing for the British Tanker Company, Limited. The engines are built by MESSRS. MIRRLEES, BICKERTON AND DAY, LIMITED, Stockport, and four TLA 6 six-cylinder engines, rated at 270 brake horse-power, at 500 r.p.m., and driving 150-kW alternators, are for the Wallsend Slipway and Engineering Company, Limited, and two similar sets are for Messrs. R. and W. Hawthorn, Leslie and Company, Limited. Fourteen Mirrlees TLA 3 three-cylinder engines, rated at 135 brake horse-power, at 500 r.p.m., and driving 75-kW alternators, are for Messrs. William Doxford and Sons, Limited; four similar sets are for Messrs. Swan, Hunter, and Wigham Richardson, Limited, and two are for Messrs. John G. Kincaid and Company, Limited.

MESSRS. BLAW KNOX LIMITED, Clifton House, Euston-road, N.W.1, announce that a contract has been signed with the Russian Trade Delegation for the supply of 210 Insley ¼-cub. yard excavators with shovel attachment.

MESSRS. MARCONI'S WIRELESS TELEGRAPH COMPANY, LIMITED, Marconi House, Chelmsford, Essex, have received an order from the Spanish Government, through their Spanish associates, Messrs. Marconi Española, for direction-finding apparatus for installation at the airports of Madrid, Barcelona, Seville, Bilbao, and other towns and cities. The order covers the supply of two very high-frequency and two high-frequency direction-finders, the former of which are capable of remote operation from distances of up to about 30 miles, over normal telephone lines, the equipment being left unattended on the site.

MESSRS. W. T. HENLEY'S TELEGRAPH WORKS COMPANY, LIMITED, 51 and 53, Hatton-garden, London, E.C.1, inform us that they are now delivering equipment under an order placed some time ago by the Turkish Post, Telegraph and Telephone Department. The order comprises 372,165 m. of star quad dry-core underground telephone cables, manufactured in accordance with the British Post Office specification and to be supplied in sizes ranging from 6 to 600 pairs. In addition, 4,000 m. of rayon-insulated lead-sheathed indoor telephone cable are being supplied. The cables are being used in connection with telephone development schemes at Istanbul, Ankara and Izmir.

MESSRS. HALL, RUSSELL AND COMPANY, LIMITED, Aberdeen, have received orders to build, for Hvalfangeraktieselskapet "Rosshavet," Sandefjord, Norway, two whale-catching steamers, 170 ft. in overall length. The propelling machinery in each vessel will consist of a Fredriksstad No. 6 double compound four-cylinder four-crank engine made by Messrs. Hall, Russell and Company. This firm have also concluded contracts with A/S Ganger Rolf, Oslo, Norway, to build two shelter-deck motor cargo liners, 258 ft. in length and designed to carry about 1,500 tons deadweight. The propelling machinery, in each case, will consist of an eight-cylinder 310-brake horse-power British Polar engine.

THE BRITISH ELECTRIC TRANSFORMER COMPANY, LIMITED, Hayes, Middlesex, have obtained an order for 45 electric power transformers for a public-supply company in South America. Ten 400-kVA, fifteen 300-kVA, and twenty 200-kVA transformers, totalling 12,500 kVA, will be supplied for use on the distribution system. All the transformers are of the three-phase, 60-cycle, double-wound core, outdoor type.

MESSRS. FERGUSON BROTHERS (PORT GLASGOW), LIMITED, Port Glasgow, are to supply to the Government of the Union of South Africa, two powerful twin-screw deep-sea combined salvage and towing vessels, one to be based at Cape Town and the other at Durban. Each vessel will be of 3,000 indicated horse-power, having triple-expansion engines of Messrs. Ferguson's design and manufacture. Modern salvage and fire-fighting equipment will be installed.

MESSRS. A. LONGWORTH AND SONS, LIMITED, Manchester, have received the order from British Railways (London Midland Region) for the renewal of gas mains and lighting equipment at the former Cheshire Lines Committee marshalling sidings, at Northwich, Cheshire.

MESSRS. CLEGG BROTHERS (BURNLEY), LIMITED, Burnley, Lancashire, are to construct the foundations for a new 60-ft. turntable at the Rose Grove (Manchester) motive-power depot of British Railways (London Midland Region).

THE HARLAND ENGINEERING COMPANY, LIMITED, Alloa, Clackmannanshire, have received an order for electrical pumping plant from the Argentine Government. It will be situated at Caballito, Buenos Aires, and forms part of a scheme developed by the Argentine Obras Sanitarias for improving and augmenting the supply of water to Buenos Aires. The pumping station will house six of the firm's "Spyrobowl" multistage borehole pumps, one of which will act as a standby. Each pump has an output of 15,400 gallons per minute at a head of 208 ft., and each is driven by one of the firm's 1,300-h.p., 6,240-volt synchronous induction motors.

LABOUR NOTES.

SPEAKING at the annual meeting of the Confederation of Shipbuilding and Engineering Unions—which took place at Weston-super-Mare last week—Sir Mark Hodgson said that the industry had an abundance of orders, but not enough steel to enable it to execute them. In Scotland, on Tyneside, and at Belfast, he had seen pockets of unemployment developing, and he had it on reliable authority that unless steel supplies are appreciably increased, the position will become worse and there will be considerable unemployment. Complaints of much the same character had come from persons employed in the agricultural machinery industry, the engineering industry, and the vehicle-manufacturing industry.

Workpeople, Sir Mark went on to say, were prepared to make any necessary sacrifice so long as they were assured that they were not making the sacrifice alone. "It is going to be impossible," he added, "to peg wages, if the costs of essential commodities are going to be allowed to rise. Our own wage claims can be fully justified under the principles of the White Paper, as our people have never at any time been amply compensated for their skill and labour and their essential contribution to the relief of the nation's needs."

Sir John W. Stephenson, of Newcastle-on-Tyne, who presented the report of the shipbuilding and repairing sub-committee, said that it was illogical for Cabinet Ministers to say that their industry was important and, at the same time, cut its supplies of steel. At a recent conference with the First Lord of the Admiralty, representatives of the Confederation had made it clear that the target set for shipbuilding by the Government and the target the industry itself thought it could reach, could not be achieved on the allocation of steel set aside for it.

A resolution was proposed expressing concern at the delay in introducing a Bill for the nationalisation of the iron and steel industries, and calling for "all possible speed" in the transfer of these industries to public ownership. Discussion, which was in places spirited, followed, and in the end it was decided, on a card vote of 830,000 to 300,000, "not to embarrass the Labour Government" in its plans to nationalise the industries.

In the course of an address to the conference, Sir Stafford Cripps, Chanceller of the Exchequer, said that millions of people still remained blissfully ignorant of the new economic conditions caused by the war and of what had been done to deal with them. The four major requirements in the field of production were volume, quality, economic price, and inventiveness. He asked delegates to be on the look-out to prevent any get-rich merchants debasing quality standards. To stop the spiral of inflation, it was necessary to stop both the price rise and the wage rise at the same time. That was the reason for the White Paper, and for the large surplus in the Budget. It was absolutely vital to our survival that we should get the position in hand.

Continuing, Sir Stafford said that we could not succeed on the basis that each section or industry should have its own way; but the others must be stopped from having theirs. No one had really suggested a departure from the free negotiations of wages and conditions. A ceiling had not been put on wages, nor had wages been frozen. What had been done had been to ask the negotiators to observe the fact that this country is sunk, if, at this moment in our history, we indulge in a general rise of wages.

Mr. George Strauss, the Minister of Supply, also addressed the delegates. The prosperity of British industry to-day depended, he said, more than anything else, on the highest possible production of steel, which required co-operation and confidence—between the employees, the Government, and the Iron and Steel Federation over the whole range of day-to-day administrative measures. That essential co-operation should not, and need not, be affected by any differences of opinion that may exist about the future of the industry. "If," he went on to say, "in our efforts to overcome the immediate problems that face the industry, the Iron and Steel Federation acts as a wing of the Conservative Party, the industry and the country will suffer."

While the executive of the National Union of Mineworkers appear to be co-operating loyally with the National Coal Board, one or two of the districts are taking independent action which is having discouraging affects elsewhere. The stay-in strikers at Waleswood Colliery, near Sheffield, are a case in point. There, the local representatives of the National Coal Board decided to close Waleswood Colliery as it was being operated at a loss, and the men replied by indulging in a stay-in strike. On the Coal Board's refusal a day or two later to reverse its decision, a second stay-in strike took place. The local representatives of the Coal Board were clearly within their rights in acting as they did, and, if the trouble is continued, several highly placed officials of the National Coal Board may resign.

Action which might seriously affect the National Coal Board's plans is also threatened in the Nottinghamshire area. The 41,000 miners in the area's 45 pits have told the officials of their union that they do not intend to work on Saturdays. The area President informed a meeting of the local council of the National Union of Mineworkers that the decision was unanimous. There was a feeling among the miners, he said, that if Saturday working were continued during the summer, they would have lost the five-day week. It was decided to urge the men to make every effort to work a full five-day week, to ensure that there was no drop in output.

The trouble at Waleswood colliery was discussed at a meeting, last week, of representatives of the Coal Board and executive representatives of the union. Lord Hyndley is reported to have stated that while the Board wished to encourage joint consultation, it had the final responsibility of running the industry. So long as he was in charge, he declared, it would remain so. If the policy were changed, he, for one, would resign.

Commenting on the position to the representative of a daily newspaper, Mr. Lawther, the President of the National Union of Mineworkers, said: "We agree absolutely with the stand taken by the Board. The Board has given us a pledge that the various changes contemplated would be discussed, first at the pit level; then, in the event of failure to agree, at area level; and, finally, if necessary, at the national level. But we have agreed also that the final decisions must rest with the Board, which is responsible for the running of the industry."

Official figures relating to the coal-mining industry indicate that the output of open-cast coal reached a record total in the week which ended on May 1. In each of the two preceding weeks, the output was also a record. Deep-mined output was 3,848,700 tons in the week which ended on May 1, compared with 3,922,000 tons in the previous week. The combined total was 4,223,300 tons, compared with 4,274,000 tons the previous week. Voluntary absenteeism among face miners rose from 7·40 per cent. in the week which ended on April 17, to 8·18 per cent. in the week which ended on April 24. Total absenteeism among all colliers rose to 11·31 per cent. Deep-mined tonnage lost through holidays, disputes and other causes, rose from 79,500 tons in the April 24 week to 112,600 tons in the May 1 week, but the output per man-shift at the coal face was 0·2 per cent. greater.

Addressing a gala gathering of Scottish mineworkers at Edinburgh, Mr. Shinwell said that there had been some "silly, fatuous, futile nonsense" talk about a deficit in the nationalised coal industry. It might be imagined from it that there never had been a deficit before. In 1925 the industry had been subsidised out of the public purse to the extent of 25,000,000*l*. Nor was that the only deficit. In fact, there had been one in the industry for many a year now. "I tell our opponents," the Minister declared, "that if they imagine that, because of certain defects, which will be dealt with, we are not going to push ahead with nationalisation in other directions, they are barking up the wrong tree. The methods may vary between one industry and another, but we shall never be satisfied until we have nationalised all the major industries of the country, and have introduced the right democratic content into the industries."

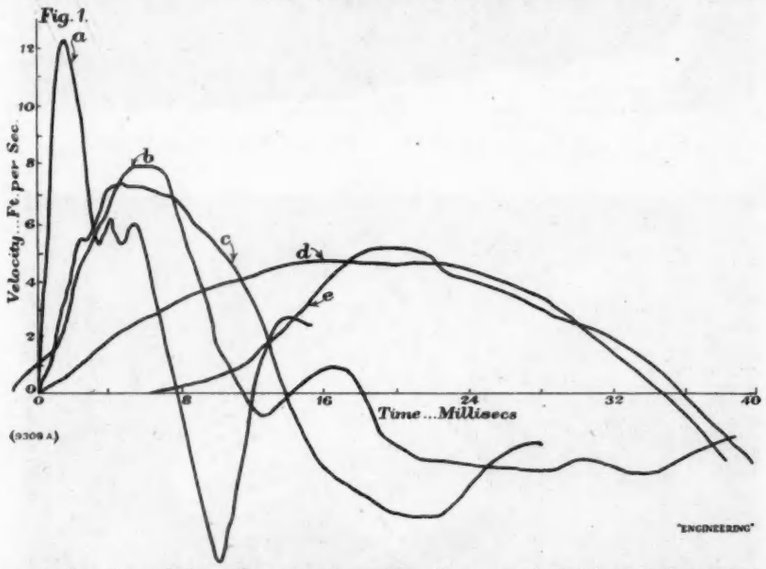
About one-half of the workers employed in cotton-spinning mills are to work overtime of half-an-hour a day in response to the Government's call for a weekly production of 20,000,000 lb. of yarn by the end of the year. One-third of the total, it is stated, are already working the overtime, and it is expected that the others will do so as a result of district ballots which are being taken by the Spinners' and Cardroom Amalgamations. The cotton weaving trade unions, on the other hand, have rejected the proposal that they should work overtime. For overtime, 20,572 votes were cast in a ballot on the subject, taken by the Northern Counties' Textile Trades Federation, and 41,545 votes were recorded against overtime.

EFFECT OF NON-CONTACT EXPLOSIONS ON WARSHIP MACHINERY DESIGN.*

By COMMANDER (E) A. D. BONNY, R.N.

BEFORE the 1939-45 war, the problem of damage to machinery due to shock had not been one of importance; the machinery was in general robust, and had withstood, without any outstanding troubles, the vibration met with at high speeds and also the shocks due to the firing of guns and the dropping of depth charges. Previous war experience had not revealed any weakness in this respect when ships were hit by shells or torpedoes, though the possibility of transmission of shock through the water had been considered in so far as it might affect condenser inlets and doors. Some damage from blast had also occurred when ship's guns were trained too close to the ship's structure. Late in 1939, however, H.M.S. Belfast was mined in the Firth of Forth by a magnetic mine on the sea-bed, and the very extensive damage to machinery and hull structure caused by this mine exploding some 80 ft. to 90 ft. away from the hull focused attention on this new type of attack. This incident was followed by many more of a similar nature, when the various types of non-contact mines employed by the enemy, as well as the explosion under water of near-miss bombs, caused a considerable number of ships to be laid up for long periods of repair. In all, over 100 ships suffered shock damage during the war—much of it of a serious nature.

Fig. 1.



Since, in general, warships are specially designed to withstand attack by torpedoes, mines, projectiles, bombs, and any other method of attack, this result was unexpected and formed a new and major problem for the naval designer at a critical period of the war. An examination of the problem showed that, in most cases, the machinery and electrical equipment suffered greater damage than the hull itself, except in those cases where the ship suffered partial collapse of the structural girder. In the case of the machinery and equipment, by far the greatest part of the damage was caused by fracture of iron castings, though considerable subsidiary damage and derangement was caused by the tripping of governors and defects in electrical breakers, lighting, and other electrical equipment, gyro compasses in particular. It is especially noteworthy that very little of this shock damage occurs from direct hits by either shell or bomb or from torpedo hits. In these cases, the local devastation is severe, but once outside the direct radius of the explosion little damage other than by splinters is met.

Though the incidence of shock damage fell off after 1941-42, due to the various protective measures against magnetic and acoustic mines, the necessity for design against shock is still of great importance. Since most of the design departments were affected by this problem, the Admiralty Shock Committee was formed to investigate the problem both in theory and by experiment. This committee has carried out full-scale experiments on H.M.S. Cameron, a Town-class destroyer; on the submarine Proteus; on a target representing a section of a submarine; and on the destroyer Ambuscade, while further investigations into the effect on larger ships are being pursued.

Taking as an example a medium-size charge of 300 lb. T.N.T. (or its equivalent of other explosive) in a container under water, then, on detonation, the solid explosive is changed almost instantaneously (about 1/20,000 second) into an equal volume of gas at a very high temperature and at a pressure of the order of 1,000,000 lb. per square inch. The water surrounding the charge possesses both a high density and a low compressibility and confines the gases in a bubble. If the charge is fired in contact with a ship's hull, the plating, which can only withstand a relatively low pressure, is blown in, and the pressure in the explosion is such that, together with the projectile effect of the splinters of plating, further inner plating is pierced unless elaborate systems of protection are fitted. The inrush of gases and splinters followed by water cause extensive local damage to any machinery in its path.

If, on the other hand, the charge is not in contact with a ship, the bubble of gases expands rapidly outwards, the pressure falling (approximately adiabatically) as the sphere of gases increases in diameter. The effect of the very rapid initial rise of pressure followed by the expansion of the bubble is to send through the water in all directions a pressure pulse travelling on a spherical front at the speed of sound in water (about 5,000 ft. per second) at a distance from the explosion, but considerably higher close to the bubble owing to the high pressures involved.

This pressure pulse has a steep-fronted peak followed by a slower fall as the bubble expands, and, as the front of the wave reaches each (spherical) layer of water, so it compresses it and gives each particle of water in the layer an outwards velocity proportional to the pressure in the wave at that point. This particle then acts on a particle in the next layer and accelerates it while bringing itself nearly to rest, thus carrying on the wave front. Once the wave front has passed, the water reverts almost to normal, having only a small outward velocity except near the bubble. Near the bubble, however, the velocity of the water is considerable, and, if an explosion occurs close to a ship, the pressure in the pulse may well be sufficient to rupture the hull, and the water between the bubble and the hull will be projected inwards, causing considerable damage.

In the general case, the bubble continues to expand until the pressure of the gas equals the hydrostatic pressure; but, since at this point the water at the boundary has considerable outward velocity, the bubble carries on over-expanding for some time until the pressure is considerably below hydrostatic. The water than reverses its flow and the bubble contracts, but again overshoots the mark, the pressure rising to a second peak and sending out a secondary pressure pulse. This oscillation of the gas bubble carries on until, consequent on the upward movement of the bubble due to its buoyancy, it breaks surface. These secondary pressure pulses are readily noticeable by an observer in a vessel close to an under-water explosion like hammer blows on the hull, and three or four are often noticed with fairly deep explosions.

While the pressures associated with the secondary pulses are considerably lower, they may be of importance if the charge is underneath a vessel, while in certain cases the maximum diameter of the bubble at the end of its initial expansion may be such that the bubble touches the skin of a ship. In this case, the ensuing contraction of the bubble will take place against the ship's side, and the maximum pressure in the second pulse may be sufficient to rupture the plating even though the initial pressure pulse was insufficient to do so.

The pressure-time curve of the initial phase has been measured experimentally by several observers, and can be closely approximated to by an instantaneous rise of pressure to the maximum pressure $p_{max.}$ followed by an exponential fall giving the pressure at any moment:

$$p_1 = p_{max.}\, e^{-nt},$$

where n is a function of the weight and composition of the charge and is given by

$$n = \frac{C}{W^{\frac{1}{3}}},$$

while $p_{max.}$ is found to decrease approximately with the distance expressed in charge radii.

Hence,

$$p_{max.} = \frac{K\,W^{\frac{1}{3}}}{D}.$$

where W = equivalent weight of T.N.T., and D = distance from centre of explosion.

From the experimental results, the various constants can be evaluated, and, if great accuracy is required, allowances can be made for dissipation losses. The equivalent weights of T.N.T. for the various explosives used for under-water work can also be obtained experimentally; non-detonating explosives, however, give very low values of maximum pressure owing to the time taken in burning.

When the spherical front of the pressure pulse reaches the surface it has to adapt itself to the atmospheric pressure that obtains there, and this can only be done by the reflection of the pulse as a negative pressure, that is, a tensile pulse. This reflection of pressure of opposite sign occurs at free surfaces in all sound and stress-wave problems. As a result of this reflected pulse, the pressure in the water just below the surface rapidly becomes negative, and when this tension exceeds a certain value (believed to be about 200 lb. to 500 lb. per square inch) the water breaks and the energy in the layer of water above carries the broken water upwards as a spray. This effect is greatest directly above the charge, falling off radially outwards due to the greater distance travelled by the pulse and to the decreasing value of the vertical component. As a result, a dome of spray rises with a fairly definite radius and surrounded by a black ring. (Here it is believed breaking of the water is still occurring, but the energy is insufficient to throw the broken water clear of the surface, although sufficient to alter its power of reflection.) The maximum radius and height of this spray dome bear a definite relation to the size and depth of the charge, and from high-speed photographs it is possible to check the depth of the explosion from this data.

Finally, the bubble breaks through the surface and projects upwards the "plume" of water and gas; this plume may vary considerably with the state of the bubble at the moment it breaks through, being most spectacular when the bubble is near a maximum pressure condition on breaking through. With deeper explosions the dome is smaller, until finally no dome is formed, a shimmer with droplets of spray occurring on the surface as the pressure pulses arrive, while instead of a plume the gases come up in a mass of creamy water.

In the case of charges either on the bottom or close to the surface, the effect on a ship will be altered by the arrival of reflected waves at a short interval after the direct pulse. In the case of reflections from the bottom, the effect will be additive, and, in the ideal case of a charge resting on a rigid sea-bed, the pressure would be doubled; however, as a rule, the increased effect is small, due to the softness of the sea floor. With a charge near the surface, a reflected tensile pulse will arrive at the ship before the direct pulse has died away and will tend to cut off the pressure in the pulse, though, since water can only withstand a limited tension, the reduction is not so large as would occur if this were not the case. In addition, with shallow explosions the bubble will break surface and vent before it has fully expanded, and the amount of energy imparted to the water will be less.

When the main pressure pulse strikes the hull of a ship, the shell plating, being relatively free to move, is given a very high acceleration and attains a velocity of some tens of feet per second in a thousandth of a second or less. The plating bends between the more rigid supporting frames, but these in turn gain velocity, the acceleration depending on the masses supported. As the pulse reaches the more distant parts, they are in turn accelerated and gain velocity, until, after 20 to 30 thousandths of a second, the whole ship has been set in motion. As the pressure dies away at any position, so the elasticity of the members will overcome the pressure,

* Paper read at the Spring Meeting of the Institution of Naval Architects, held in London, March 17 to 19, 1948. Abridged.

and the part will tend to oscillate back to its position of rest at its natural frequency, generally with considerable damping. If the movement of the plating is sufficient to cause plastic strain, the plates will be dished inwards, giving the typical "hungry look"; severe dishing is usually accompanied by distortion of bulkheads, etc.

As the various sections of the ship are set in motion at different periods of time, the ship as a whole is deformed and, in addition to the local oscillations of plates and frames, larger items, such as bulkheads, will tend to vibrate, and, in turn, the whole ship will vibrate as a beam with two or more nodes. This latter is called whipping, and its magnitude varies considerably with the position of the explosion. This whipping, though involving considerably lower accelerations than the initial shock on the arrival of the pulse, is associated with large displacements up to 1 ft. or 2 ft., and is the phenomenon most noticeable to the human observer. It may also cause the throwing about of loose objects and damage to items on certain types of mountings. In addition, the interval between successive pulses is often of the same order as the period of whipping of the ship, so that, with charges nearly under the ship, a considerable increase in whipping may result from the secondary pulses.

In considering further the transmission of the pulse to parts inside the ship, it is necessary to consider the theory of propagation of stress. If an impactive blow be given to one end of a bar of metal, a wave stress is propagated along the bar at a velocity equal to the velocity of sound in the metal, viz., $\sqrt{\frac{E}{\rho}}$, where E = Young's modulus and ρ its density. This wave of stress is similar to the pressure pulse in the water, except that, in this case, the motion is on a plane front instead of a spherical. Again, each particle in being pushed by and pushing on its neighbours attains a momentary particle velocity proportional to the intensity of the stress.

When such a stress reaches a free end, then, as in the case of the free surface of the water, a wave must be reflected back along the bar of opposite sign (pull instead of push) to make the stress zero, and such stress will oscillate to and fro until it dies away. If, on the other hand, it strikes a rigidly fixed end, the reflected wave will be of the same sign, and a force equal to twice the blow acts momentarily on the fixed surface. Similarly, with partly fixed ends and changes of section, varying reflected waves will be caused, and these waves can be superimposed to give the total stress at any instant at any position. Such waves occur even with normal rates of loading, but in view of their velocity (16,700 ft. per second in steel) the variations in strain caused by them are negligible. Even in the case of the shock wave experienced by light machinery items, the time of application of which is some 2 to 3 thousandths of a second, the effect of such wave propagations of stress does not show on records and can normally be neglected.

The pressure pulse having caused the plating and frames to deflect, these items, in turn, will exert forces on the various seatings, bulkheads, etc., and hence on the machines and fittings mounted on them. Depending on the items involved, the masses will be accelerated up to appreciable velocities, and, as the pulse dies away, they are brought to rest by their fastenings or internal stresses. The resulting effects are many and varied. From the initial pressure pulse result the very considerable fractures of main and auxiliary machinery and stretching of holding-down bolts; while, from the later whipping, cases have occurred of priming of boilers, throwing around of floorplates, ladders, and other loosely secured items, and the tripping of governors on dynamos, feed pumps, etc., besides the very considerable effects noticed on electrical machinery and equipment, gun mounting, rangefinders, and the small items such as wireless and radar and their aerials and arrays.

To be able to design machinery to withstand shock, it is obviously necessary to get a fairly close approximation to the motion undergone by the body, so that a knowledge may be obtained of the accelerations to which a body may be subjected and their duration, as, in general, failure of a body is caused by relative motion; thus, except for the most brittle materials, fracture is always preceded by strain, which involves movement in the body. However, as is the case with all calculations involving complicated bodies, such as ships' structures, there are too many factors about which insufficient data are as yet available to permit of a detailed calculation of shock effects.

Such factors are: the stiffness of the skin plating and its associated framing and the energy absorbed in dishing of the plating and distorting the frames; the effect on such stiffness of added members, supports for machines, bulkheads, etc., and the resultant motion of the platforms and seating of machines, etc.; the increase in yield point and ultimate tensile strength that occurs when metals, particularly low-carbon

EFFECT OF NON-CONTACT EXPLOSIONS.

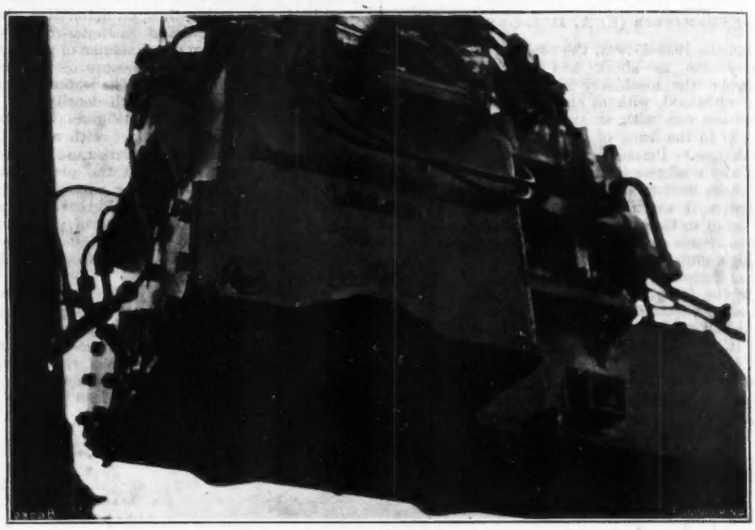


FIG. 2. BASE OF GENERATOR FRACTURED BY DECELERATING FORCES.

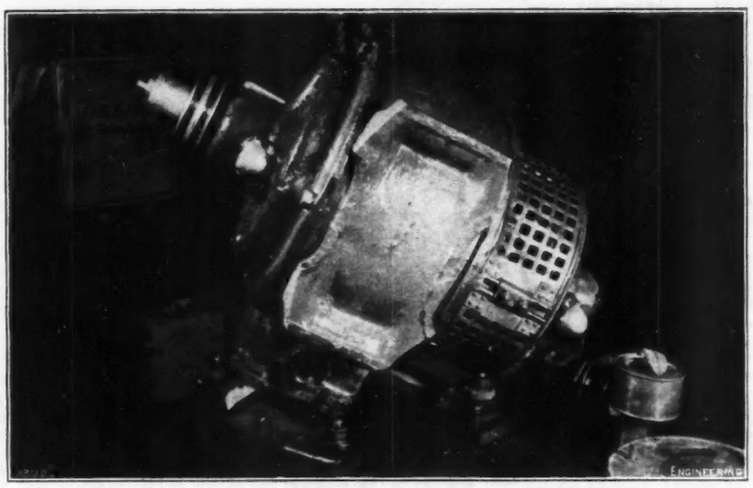


FIG. 3. FRACTURED BASE OF ELECTRIC MOTOR.

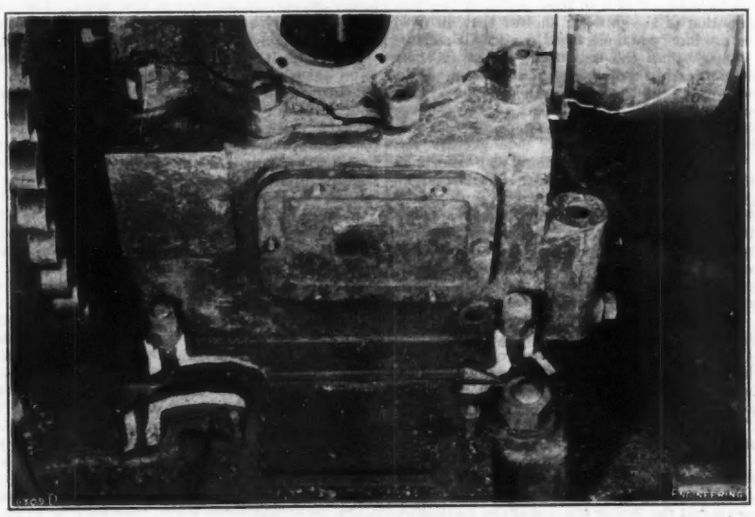


FIG. 4. DAMAGED ENGINE CRANKCASE.

EFFECT OF NON-CONTACT EXPLOSIONS.

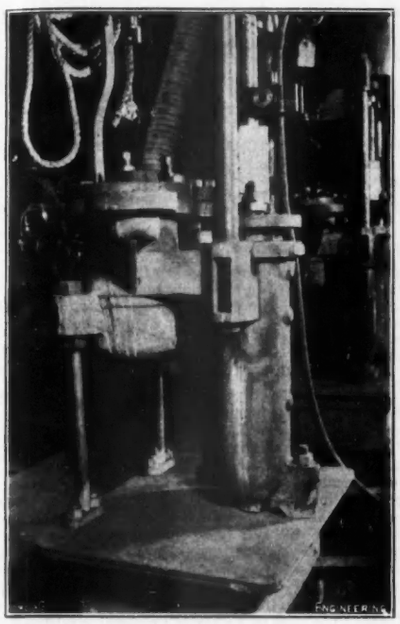


FIG. 5. PUMP BEFORE SHOCK.

FIG. 6. SHOCK DAMAGE TO PUMP FOOT.

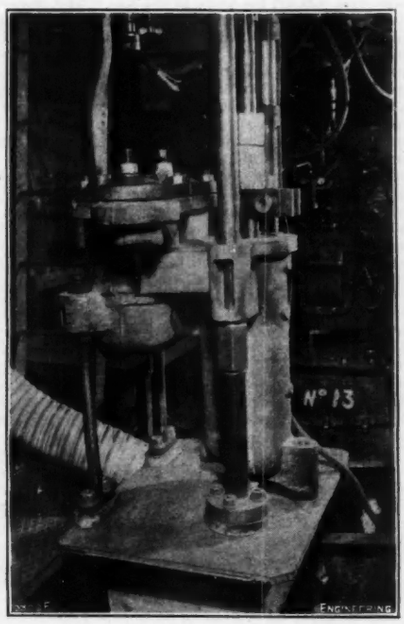


FIG. 7. STRENGTHENED PUMP AFTER HEAVIER SHOCK.

steels, are subjected to rapid loading; the effect of the reflections of the pressure pulse from the sea bottom and surface, and diffraction of the pulse around corners; and the reflection of the pressure pulse from the moving ship's plating and whether in certain circumstances this leads to cavitation in the water close to the plate—a matter the effect of which is most difficult to assess. Nevertheless, a reasonably close approximation to the velocity that an item would attain, together with an appreciation of the acceleration, can be obtained from consideration of the behaviour of an unrestrained flat plate subjected to a pressure pulse.

Though, in fact, the ship's structure consists of relatively thin plates formed into panels by longitudinals and transverse frames, consideration of the various aspects of the problem shows that, when considering fairly concentrated items of equipment, the error is small if the item is taken as equivalent to a plate of the total supported weight divided by the area contributing to its motion. This is particularly so since, for the weights per unit area commonly met with, the proportion of energy absorbed varies only slightly from a mean figure of approximately 0·5. Thus, provided a reasonable assumption of the area contributing to the motion can be made, the maximum velocity of an item can be obtained from a formula

$$\tfrac{1}{2} M V_{max.}^2 = \text{constant} \times \frac{W \sin \theta}{D^2}$$

$$V_{max.} = \frac{K}{\sqrt{M}} \frac{\sqrt{W \sin \theta}}{D}.$$

Such an approximation, however, applies only up to the elastic limit of the structure under consideration, and above this, the plastic deformation of the hull plating and frames will result in the absorption of energy that would otherwise contribute to the motion. The effect of plastic dishing is again, as yet, incalculable, and must be founded on practical experiment; since the average ship will only stand a very few shocks of this magnitude, this is both long and costly. Sufficient data are available, however, to give an overall picture (Table I) of the accelerating forces which items may have to withstand when subjected to a shock wave that just ruptures the hull. The greater the mass per unit area of hull, the lower the acceleration; while position in the ship has a considerable bearing. The motion of typical items such as the above can be seen from Fig. 1, on page 477, showing velocity-time records as recorded by the seismographic type of velocity meter on actual trials. In this group of records, curve *a* relates to the hull plating; *b* to a bulkhead; *c* to a mass of 1 ton on a seating in a boiler room; *d* to a similar mass on a 1-in. rubber mounting; and *e* to a 1-ton mass slung under the deck.

A warship is designed, according to its class, to stand a certain degree of punishment, and what is desired is that all the functions of a fighting ship can be carried out to the moment when the ship is so badly damaged that she can only limp to a refitting port. It is essential that no one type of damage shall cripple her at an earlier stage than can be helped, nor should the refitting be unduly prolonged owing to the predominance of damage that cannot be readily repaired. Such damage, in the case of a reciprocating dynamo, is illustrated in Fig. 2 opposite.

It was in this respect that shock damage was so serious, the replacement of large and intricate castings being a lengthy process taking a considerably longer period than the hull repairs. To obtain a balance of

TABLE I.—*Accelerating Forces.*

——	Accelerations.	Duration in Thousandths of a Second.
Shell plating	Several thousand *g*	1 or less
Items mounted directly on frames	100-300 *g*	2 to 5
Average auxiliary	100-200 g.	3 to 10
Section of ship vibrating ..	50-100 *g*	5 to 15
Ship whipping as a whole ..	2-5 *g*	Several hundreds

qualities, it has been decided that items should be able to withstand shocks to the point at which uncontrollable flooding occurs in the compartment in which they are situated. Since the ship is then in a bad way, no factors of safety are required, and, in fact, it is probably sound design for certain parts of an item to have yielded at this stage, provided that the machine will still just function and the yielded parts are easily replaceable.

Design figures for accelerations to be worked to are the next essential, and, as an example, the average auxiliary should be able to withstand 120*g* upwards, 60*g* downwards, and 40 to 60*g* athwartships. Certain other figures for special cases have been promulgated from time to time, but it is to be hoped that a more comprehensive list of design figures can be supplied to machinery designers when the experiments now in hand have been completed.

Next, it is desirable to define more closely the above figures of accelerating forces, etc.; thus, an auxiliary machine designed to these figures should be capable of withstanding a force equal to, but not exceeding, 120 times its weight applied to its base for an indefinite period. Next, the base slows down and applies through the holding-down arrangements a retarding force of 60 times the weight of the machine indefinitely. A further requirement is that it can stand the base moving athwartships and applying a force of 40 to 60 times the weight of the machine. Though, in fact, the accelerations may be of short duration, they may exceed those figures, and they are given as of indefinite period to simplify the design problem.

The stresses caused in the machine by these forces fall into three principal types, namely, direct compressive (or tensile) stress due to the acceleration of a mass through a supporting column, which seldom cause failure; bending stresses during acceleration due to the force not acting through the centre of gravity of a specific part of the machine—a common cause of failure; and bending stresses during deceleration due to the holding-down arrangements acting on the feet of the machine and causing these to fracture or the holding-down bolts to stretch—a very common result (see Figs. 2, 3 and 4, opposite).

If the materials used in construction are brittle, fracture will occur. It was evident from the first that cast iron was the chief sufferer from this type of damage, whereas ductile materials, which not only had a higher strength but could yield and distort slightly without necessarily putting the machine out of action, were seldom affected seriously except in cases of very poor design. The prohibition of cast iron for all except a few items where its properties merit its special retention under due safeguards was the first obvious step, but could not be fully implemented because of production difficulties in war-time. Cast aluminium is a similar source of weakness; gunmetal is better, provided that a reasonable ductility is assured.

In addition to the avoidance of brittle materials, shock design requires the placing of the feet or supporting chocks and the design of the base so that the forces are transmitted directly to the main mass of the machine; design of the feet or bedplate and its holding-down arrangements so that the decelerating forces will not fracture or distort the main body of the machine (stretching of holding-down bolts or distortion of keeps is probably acceptable); suitable design of all overhanging masses and their supports to avoid excessive bending moments; and dynamic balance of trip gears and similar mechanisms so that shock does not tend to trip turbo-generators, etc.

Design for the first and third requirements is not difficult as a rule, while the second can be safeguarded by making the holding-down bolts with adequate stretching lengths and considerably weaker than the foot; similarly, keeps can be designed so that they will yield before the foot breaks. Thus, if 16 tons per sq. in. be allowed for a mild-steel foot that should not yield, then the holding-down bolts or keeps should be stressed to 25 tons per sq. in. under these conditions to ensure yielding. Even higher stresses would not be amiss, for, owing to the short duration of the decelerating period, the actual elongation will be very small. The effect of such design in minimising damage is clearly shown in Figs. 5, 6, and 7 of an original and modified type of Weir's pump tested on a ship. It is also good practice to mount auxiliary machinery on a fabricated bedplate or deep girder so that any slight movement of the base does not cause misalignment.

(*To be continued.*)

ANNUALS AND REFERENCE BOOKS.

Spectrochemical Abstracts. Vol. III (1940-1945).—The two previous issues of these spectrochemical abstracts covered the years 1933-7 and 1938-9, respectively. In the present volume, the numbering of the abstracts (395 to 862) follows consecutively those in earlier volumes. Part I contains a list of authors and references, arranged alphabetically under the authors' names, followed by two indexes of elements observed as minor constituents in the analysis of non-metallic or metallic substances, respectively, in which only those papers giving the wavelengths used are included. A list of the journals abstracted would be a useful addition to this section. In Part II, the abstracts themselves are classified under the headings of substances analysed (biological materials, ceramics and slags, gases and liquids, minerals and ores, non-metallic solids, metals); apparatus, methods, source theory, summaries and reviews, and books. It is pointed out that the subject-indexing of papers under the headings of methods, apparatus and theory is arbitrary and that sub-headings have been introduced to indicate what, in the opinion of the abstractor, was the chief topic of the paper, whether the author mentioned it in the title or not. To compensate for these purely personal decisions, copious cross-references have been inserted. The abstracts range in length from 30 to 300 words. The care taken in the abstracting and over the classification of the material abstracted makes this publication a valuable source of reference to workers in this important and expanding field. The editor is Mr. Ernest H. S. van Someren, and the publishers are Messrs. Adam Hilger, Limited, 98, St. Pancras-way, Camden-road, London, N.W.1. The price is 12*s.* 6*d.* net.

British Standards Yearbook, 1947.—The Yearbook of the British Standards Institution for 1947 has recently come to hand. As has been the case with previous issues, it contains a synopsis of each of the 1,400 British Standard Specifications now current. The synopses are given in numerical order and a detailed subject index is furnished. Lists of members of the General Council, and of the Building, Chemical, Engineering, and Textile Division Councils are included. Full particulars regarding the standards committees, representing 50 different industries and responsible for the preparation of the specifications, are also given. The Institution issue monthly information sheets regarding the publication of new specifications and these maintain the numerical list in the Yearbook up-to-date. A pocket is provided at the back of the Yearbook for convenience in filing the sheets. Copies of the Yearbook, price 3*s.* 6*d.* postage included, can be obtained from the Publications Sales Department of the Institution, 24, Victoria-street, London, S.W.1.

ABC World Airways and Shipping Guide.—The issue for mid-April to mid-May of this now well-known guide to air travel is in a new format, measuring 9¼ in. by 8 in. It is divided into a number of sections, the first of which contains a list of the world's airlines and general information for travellers regarding baggage, currency and Customs regulations, and the like. A gazeteer then follows, giving complete reference to all places shown in the guide together with fares, air-cargo rates and other charges. The third main section is devoted to time tables of the world's air services, and the fourth to time tables and tariffs of shipping services from the United Kingdom and Western Europe to other parts of the world. The guide concludes with lists of aero clubs, aviation organisations in this country and other matters of aeronautical interest. The proprietors of the guide are Messrs. Thomas Skinner and Company (Publishers), Limited, 330, Gresham House, London, E.C.2. It is published monthly, price 3*s.* The annual subscription is 2*l.*, post free (by surface mail) to any part of the world.

CATALOGUES.

Grinding Machines.—The wide range of grinding machines manufactured by the Churchill Machine Tool Company, Limited, Broadheath, Manchester, is briefly described and illustrated in a substantial catalogue received from them. Every standard type is dealt with, including plain cylindrical, universal, internal, surface, locomotive-axle, crankshaft, roll, centreless, thread-grinding and slideway-grinding machines.

Gears.—Messrs. John Holroyd and Company, Limited, Milnrow, Lancashire, have issued a handsome book dealing with the manufacture of gears. They produce many types, including worm, spur, helical, double-helical, and spiral gears, racks and pinions, bevel, sprocket, and totally-enclosed reduction units, etc. These, and other types, are described, and there are informative chapters on machining, hobbing, and grinding; the accuracy of gears; materials and research. The book is well illustrated and shows the high standard of manufacture which has been maintained by the firm for many years.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communications are given in italics.

*Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1*s.* each.*

The date of the advertisement of the acceptance of a Complete Specification is given after the abstract in each case, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

595,263. Differential Electrical Apparatus. H. M. Powell, of Thames Ditton, Surrey. (6 *Figs.*) December 13, 1944.—This invention can be employed to indicate, measure, give warning of, or to apply correction for, a difference between any two quantities being compared, provided that one quantity can be represented by a continuous rotation and the other by periodic impulses. The application described is the correction of a synchronous clock by a master clock. As shown in Figs. 1 and 2, a rotating member consisting of a soft-iron dipolar armature 1 has a central hub portion 1*b* frictionally engaged with the driving spindle 2 by means of a dished spring spider 7 located between one hub-end and a collar 8 on the spindle and nuts 9 screwed on the latter to engage the other hub-end. The spindle 2 is driven by a synchronous electric motor 3 through suitable gearing so that it will rotate at one revolution per second, when the frequency of the alternating current supplied to the motor is exactly 50 cycles per second. The hub has gear teeth 10 to form a pinion and a train of gears (not shown),

Fig.1.

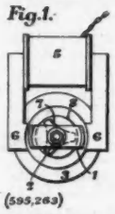
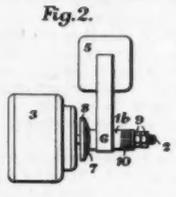


Fig.2.



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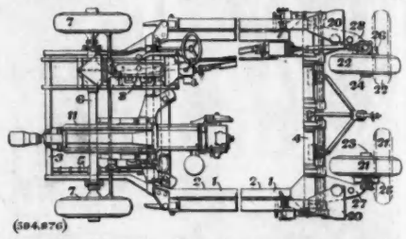
driving a pointer over a graduated dial. A master clock (not shown) transmits electric current impulses of short duration at a frequency of one per second, to the windings 5 of an electromagnet having pole pieces 6. The pole pieces 6 are arranged so that the armature 1 rotates in the gap between them, the initial setting of the armature on its spindle 2 being such that it is exactly central with the pole pieces at the instant that an impulse is transmitted by the master clock. The armature 1 rotates between the pole pieces 6 of the electromagnet at a speed proportional to the frequency of the alternating current supplied to the synchronous motor 3. So long as the frequency of the current is correct, the impulses have no effect on the armature. Should the frequency rise or fall somewhat, the armature will reach its central position proportionately earlier or later than the next energisation of the electro-magnet, and will be restored to the exact central position by the pull of the electro-magnet. The mechanism thus operates as a synchronous motor-driven stop-clock having correction applied by a master clock at one second intervals. (*Sealed.*)

GUNS AND EXPLOSIVES.

594,876. Gun Carriage. N. Straussler, of London. (5 *Figs.*) December 8, 1942.—The invention is a self-propelled gun carriage arranged so that the carriage can be traversed in a limited space. A chassis frame 1 has side members 2, and transverse end members 3 and 4. The chassis frame is supported at the front through semi-elliptical leaf springs 5, on a differential steering axle 6 having road wheels 7, driven by an internal-combustion engine 8 through a change-speed gear box. The gun 11 is arranged at one side of the engine, the mounting being provided with recoil gear and manually operable traversing and elevating mechanism. Reaction spades 20 are also provided which can be lowered to dig into the ground when the gun is fired. The rear of the chassis frame is supported on two road wheels 21 and 22, each of which is mounted for rotation on a tubular stub axle as indicated at 23 and 24, each stub axle being carried by a casing 25 and 26. The casings 25 and 26 are pivoted on brackets 27 and 28 for movement of the wheels 21 and 22 about vertical axes. The wheel 22 is provided with gearing in its casing 26, whereby it can be driven from the power unit and with hydraulic brake gear. Provision is also made for raising or lowering the chassis frame relatively to the rear wheels, as required. Since the rear wheels can be moved to the positions shown in chain-dotted lines, and locked about their vertical axes, it is clear that the whole vehicle can be traversed about a vertical axis



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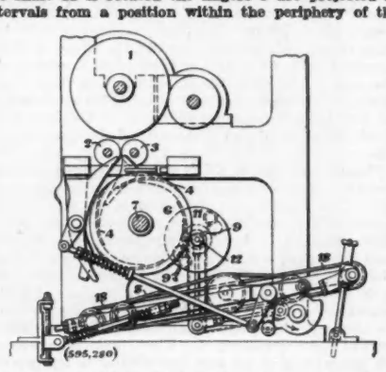
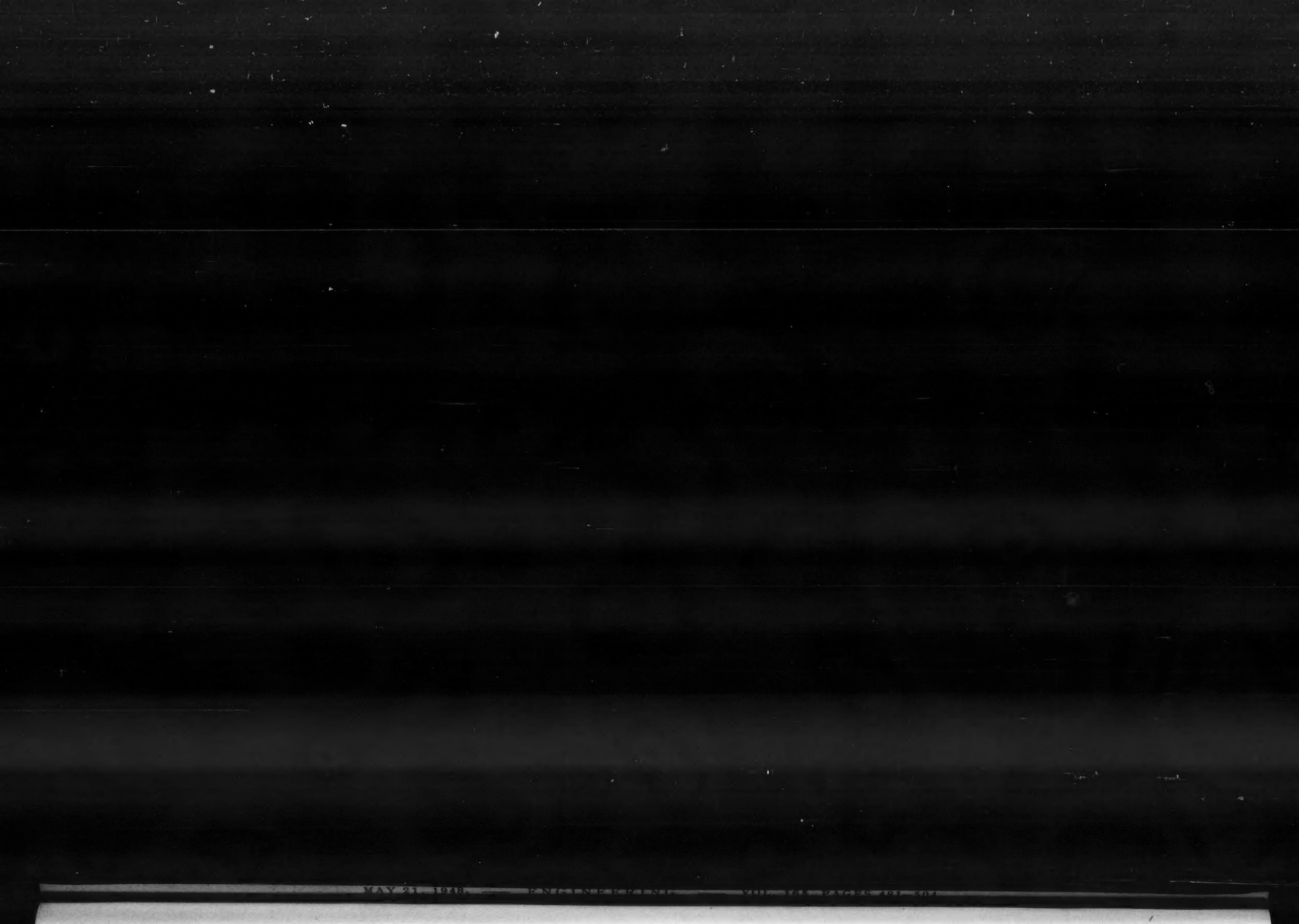
intersecting the mid-point of the front axle, by driving the wheel 22. If desired, only one rear wheel may be provided, placed midway between the positions of the wheels 21 and 22 and driven in a similar manner to the wheel 22. (*Sealed.*)

PRINTING AND ALLIED MACHINERY.

595,280. Delivery of Printed Sheets in Counted Batches. R. Hoe and Company, Limited, of London, and C. H. Skinner, of London. (4 *Figs.*) April 9, 1945.—This apparatus is for use with a printing machine to deliver printed sheets in separated batches each of a predetermined number. The folding cylinder 1 of a printing machine of the usual type delivers printed products into folding off rollers 2, 3 from which they pass into the pockets of a delivery fly consisting of a number of discs 6, each having arms 4, the discs being mounted on a driven shaft 7. In the normal operation of these delivery fly devices, products are taken round by the fly and deposited on a series of endless bands 8 so that the products pass away in overlapping relationship, the products being "stripped" from the fly by ejector discs 11. In this apparatus intercepter fingers 9 are carried on spindles mounted to rotate in the discs 11. These discs are mounted on a shaft 12 driven in timed relationship with the delivery fly, which itself is driven in timed relationship with the printing press. Thus, as the shaft 12 is rotated the fingers 9 are projected at intervals from a position within the periphery of the



(595,280)

discs 11 to a position outside that periphery. In order to give to the intercepter 9 a rapid movement when it is being projected outwardly into operative position, mechanism is provided to impart to the intercepter two motions which are additive while the intercepter is passing out and are subtractive during withdrawal of the intercepter to give a slow withdrawal. The timing of the fingers 9 is such that as the last one of a batch of products is being delivered to the belts 8, the fingers 9 come quickly into a position to intercept the first few copies of the following batch. The belts 8 are driven at a speed governing the requirements of pitch of the printed products and are interleaved with belts 18 driven at a speed greater than that of the belts 8. At regular intervals the belts 8 are lowered to slightly below the belts 18; thus as these belts 18 are running at a higher speed, the products which have been deposited on the belts 8 are taken and accelerated by the belts 18 from the fly zone. This operation of the belts 8 is timed to synchronise with the operation of the fingers 9. By reason of the acceleration imparted to a batch by the belts 18 that batch will be taken ahead of the products of the succeeding batch and so will establish a gap between the two batches and thus the required space separation into counted batches is achieved. (*Sealed.*)

INSTITUTION OF LOCOMOTIVE ENGINEERS.—The annual reception and luncheon of the Institution of Locomotive Engineers, 28, Victoria Street, London, S.W.1, will be held at the Dorchester Hotel, Park Lane, London, W.1, at noon on May 28. Applications for tickets should be in the hands of the secretary by May 18.